The Association
of
Engineering and Shipbuilding
Draughtsmen.

An Introduction To Press Tool Design.

By J. PALMER.

Published by The Association of Engineering and Shipbuilding Draughtsmen
Onslow Hall, Little Green, Richmond, Surrey.

SESSION 1957-58.

Price 3/-

Printed by Milne, Tannahill & Methven, Ltd. (T.U.), 12-14 Mill Street, Perth.

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AN INTRODUCTION TO PRESS TOOL DESIGN.

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INTRODUCTION.

Almost any metal part can be made by a sufficient number of pressworking operations. In many instances, of course, this is undesirable and uneconomical.

Pressings during the war were accepted to a certain degree as an expedient, but many of the ideas and processes involved have remained as production methods that once were considered to be too costly. War-time proved the practicability of producing pressed parts that were formerly made from forgings or castings. It also proved that a degree of accuracy could be maintained to meet many requirements, that a considerable saving of material could be effected and that pressed parts could be made faster and more economically than by other processes, whilst the loading on other machine tools could be reduced.

Ideally, a pressed part should be made in as few operations as possible. To this end, the layout, planning and designing of press operations depend to a great extent upon knowing the capabilities and capacities of the presses available. The tool draughtsman should know the ram and bed sizes, the crankshaft diameter, the stroke, and also the daylight with stroke and adjustment down, and this information should be tabulated for reference.

The pressed part should be designed in such a manner that the press tool can be constructed in the simplest form possible and it is here that close co-operation between the design and production department is essential.

Simplest tools are best. The tool designer must ensure that no unnecessary parts are used and moving parts kept to a minimum; and he must study the punch and die form from a point of view of distortion and machining after hardening. Hand work should be kept to a minimum and where intricate forms cannot be avoided it may be advisable to split the die and make it in a number of parts. The whole tool has to withstand a great amount of load, and must therefore have a very robust construction.

Where the application of a mechanical movement is desirable, it may be an advantage to lay down on a board, cardboard templates with pins stuck through the fulcrum points, so that the movement can be clearly seen and the necessary clearances determined.

A great deal of experience is needed to foresee the many snags that are met in the varied applications of press work, but an attempt has been made in the following pages to describe and illustrate some of the more common principles involved.

CHAPTER 1.

PRESSES AND ATTACHMENTS.

In a well equipped press shop the selection of the correct press depends mainly upon the stroke, the pressure required for the operation, and the size of the tool. In smaller factories, however, the ingenuity of the draughtsman in adapting his tool designs to suit the available equipment can increase the output of pressed work from a limited number of machines.

There are numerous kinds of presses on the market, but below are listed the more common types that are likely to be encountered.

The Foot Press.

This is the least powerful press, has an adjustable table, and is used for punching single holes in light gauge material. A horn can replace the table to take hollow work.

The Arbor Press.

Usually a bench mounted machine, this press is operated by a handle connected to a pinion, geared to a rack integral with the ram. It is used for experimental and light work and the operator can feel the pressure he is exerting. Another type of Arbor press is operated pneumatically with an air cylinder mounted behind the ram, and is used for blanking, rivetting, broaching and similar operations.

The Fly Press.

This is another hand-operated, bench mounted machine, similar to the Arbor press, but has a large square thread lead screw and nut and is operated by an overhead horizontal handle, weighted at one or both ends. The machine is used for light work and it is common to find one in the tool-room for pressing bushes into drill plates and for trying out larger tools to test their mechanical action and alignment.

Single Acting Gap Frame Press.

This machine is one of the main types and is made in many sizes. Some are inclinable, swinging back to 45° so that the formed work can drop away by gravity. They are used for single acting and combination work including blanking, piercing, bending and light drawing. The ram is operated by a crank or cam and the machine is suitable for use with roll feeds and in most operations where strip material is used.

Straight Side Press.

This is another widely used machine and usually incorporates a variable speed motor so that the press can run at a speed most suitable to the work. This press operates at a high speed and roll feeds and scrap cutters are frequently used in conjunction with it. The construction being more rigid than the gap frame press, it is used for heavier work, its capacity ranging up to 500 tons.

Punch and Notching Press.

This machine is designed with a deep gap in the frame to accommodate large sheet material. It has a very short stroke and usually cuts one hole at a time. On some models a cropping attachment is incorporated into the side of the machine and the ram mechanism is operated by a footpedal.

Double and Triple Acting Presses.

Used for blanking and drawing, or when two operations are co-related, the double acting press has its outer ram or blank holder operated by a cam or toggle link, and an inner ram which performs the blanking, sliding inside the outer ram.

The triple acting press has a similar action, but also includes a third ram acting upwards, squeezing the metal between it and the inner ram. This machine is commonly used for deep drawing, coining and embossing operations.

Arch Presses.

The arch type, so called because of its high frame, is a straight sided machine and has a large bed area, making it suitable for large sheetmetal work. Blanking, trimming and bending work is performed on it and the work is fed in from front to back. The machine can be supplied with a long stroke making it suitable for deep drawing.

Knuckle-Joint Presses.

Used mainly for coining, embossing and extruding, these presses are made with a large tonnage capacity. The ram is operated by a knuckle joint and has a short stroke.

Hydraulic Presses.

These are built with pressures of up to 5,000 tons and have the hydraulic unit mounted on top of the press. They are frequently made with four pillars, this feature ensures that an even pressure is exerted at the four corners and counteracts the weight of large uneven dies.

Press Brake.

This machine is used for line punching and for bending and forming long strips of material. It is made 6′ 0″ to 15′ 0″ long and usually worked by two operators. It is a very versatile machine, and the ram on a hydraulically operated model can be stopped in any position of its downward stroke.

Press Attachments.

The commoner attachments that are fitted or work in conjunction with the press where strip materials are used, include reels, cradles, straighteners, roll feeds, and oilers. These are used extensively with high speed machines when long automatic runs are performed.

The number of components that can be produced before the tools need attention is known by experience, and many presses incorporate an automatic counter which records the number of ram strokes, thereby informing the operator when to stop his machine.

Reels.

Stock reels are made adjustable to suit varying widths of coiled strip, are adjustable for height and run on ball bearings. The plain type is provided with a brake to prevent the strip over-running.

The motor driven reel has a feed mechanism which prevents the strip being pulled and ensures accurate feeding and eliminates strain. They are used when long runs demand a heavy coil of strip, and both vertical and horizontal types are available. Cycle feeds are obtainable which can feed any pre-set length automatically.

Cradles.

These serve the same purpose as the reels, and are adjustable for width of strip. There are also plain and motor driven types which are used in preference to the reel when heavier stock is needed.

Straighteners.

Used in conjunction and often made integral with either the reel or the cradle, the straightener is placed between it and the press and is used to ensure that perfectly flat strip is fed over the die. Again, both plain and power driven straighteners are available, the plain type being used when the feed mechanism is powerful enough to draw the material through the straightener.

It consists of a series of rollers, the top ones being adjustable for various thicknesses of stock, and is adjustable in its width.

Wire straighteners consist of two independent sets of rollers, the sets being at right angles to each other, so that the wire is straightened in two planes.

Roll Feeds.

Roll feeds are used on gap frame and straight side presses and are either made singly or in a set. Their object is to feed and position the material on the die before the ram descends.

The single type is used when working with strip that is thick enough to be pushed over the die without buckling, whilst the double type is used for lighter gauge material. They are operated by a slotted toggle on the crankshaft, to which a lever is attached, which in turn actuates a rack and pinion on the feed roll. The length of material fed can be changed by altering the position of the lever in the slotted toggle.

When the strip is located by a piloted punch, the ram on its descent operates a lever which opens the feed rolls to prevent any material drag, and this lever is also used when inserting a new roll of strip.

Oilers.

Oilers are located next to the die and can be incorporated in the tool. The simplest type allow the strip to pass between two felt pads which are fed by a drip feed.

Scrap Cutters.

These are actuated by the ram, usually operate with each stroke and are placed so that they cut the scrap strip into easy handling size after it has been fed through the press tool. The scrap cutter can also be built into the tool when quantities allow it.

Adjustable Knockouts.

These are made in two types. One is attached to the ram slide, and can be adjusted to any position ejecting the work from the top former. The other is located under the tool in the machine bed, is cam operated and ejects the work from the bottom former.

Knock Off Fingers.

These are fitted to the side of the press and designed to sweep over the die surface after the forming operation has been completed, thus clearing the part away from the tool and preventing two components jamming. They are used when the formed part is ejected back through the die, as in a flanged drawn cup, and for parts which cannot be pushed through the aperture in the press bed.

Another way of removing the finished work from the die surface is to use compressed air, either continuously or intermittently, when the ram is on the upstroke. Apart from clearing off the component, the air also removes any swarf which, if left, could injure the tools.

Chutes and Magazines.

There are many types of chutes, each being designed to suit the component being made. They can be built into the tool or separate from it and are used for feeding the work into the tool and for leading it away. For high speed work, the magazine is essential, allowing one blank at a time to be fed into the tool and being controlled either manually or by a cam fitted to the crankshaft.

Up to eighty blanks a minute is the usual number when manually feeding the magazine, and above eighty per minute when the magazine is fed automatically.

Hoppers.

Hoppers are frequently used in conjunction with the chute and magazine, particularly when the die blank is small. They should be designed when necessary to allow the part to be fed into the die in only one way. One method of doing this is to have a driven oscillating arm agitating the components in the hopper until they are fed in their correct position into the chute. There are many other methods, limited only by the ingenuity of the designer.

Chapter 2.

PUNCH AND DIE DETAILS.

Clearances.

Clearance is always provided between punch and die, the punch being smaller than the die (see Fig. 1) at "*a*". The reason for clearance is that it reduces the blanking pressure and helps the shearing action. It also prevents the contact between punch and die chipping or breaking the cutting edges. For materials of $\frac{1}{64}$" or less in thickness, the punch should be a sliding fit in the die. For thicker materials, the punch should be made less by 5% of the material thickness for brass and soft steel, 6% for medium steel and 7% for hard steel. It is pointed out here that the tool drawing should state clearly whether the clearance is on one side or all round.

Too great or too small a clearance affects the smoothness of fracture. Too great a clearance will give a raised edge on the

blank, while too small a clearance will result in premature wear on the tool and a risk of breaking it.

It should be noted here that when the punched hole must be a finished size, the punch must be made to that size and the clearance added to the die, while conversely, when the blank is the finished product, the aperture in the die must be made to that size and the clearance deducted from the punch.

In other words—**the punch governs the size of the hole and the die governs the size of the blank.**

An angular clearance (see Fig. 1) is usually provided below the cutting edge of the die in blanking tools. This is to prevent the punchings from jamming in the die, for if this happens the tool may have to be stripped down and the punchings drilled out. When quantities are small, or the material to be cut is soft, or if the finished size is un-important, the angular clearance can be brought directly from the cutting edge as shown at *"b."* For harder materials, and when large quantities are required, a land of $\frac{1}{16}''$ to $\frac{1}{4}''$ is provided below the cutting edge, as shown at *"c."* This is to enable the die to be reground on its surface when the cutting edge becomes blunt, without altering the size of the blank.

The angular clearance is usually $\frac{1}{2}°$ for brass and steel and 1° for aluminium.

When a stripper plate is not used an angular clearance shown at *"d"* is also provided on the punch, to facilitate the strip being removed.

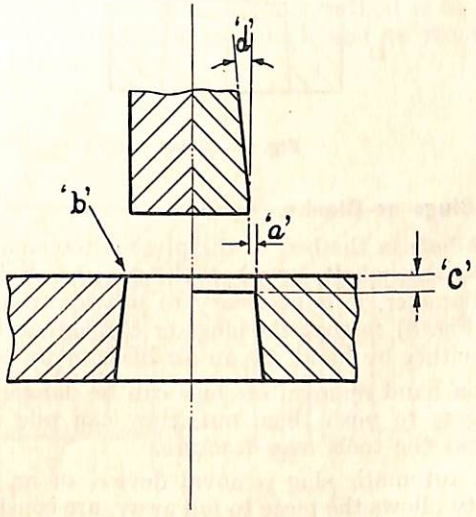


Fig. 1—Clearances on Punch and Die

Shear.

The use of shear (see Fig. 2) on either punch or die reduces the total blanking pressure, gives a smoother action, and lessens the wear on the tool. The reduction in blanking pressure is as much as 25%, but the height "*x*" of the shearing angle should not exceed the stock thickness, or the blank will be distorted. It should be noted here that when the blank is to be the finished article, the shear must be on the die as at "*b*", whilst the shear must be on the punch ("*a*") when the blanked hole is part of the required article.

In some cases, using a shear on the die is not satisfactory for it can make the location of the work difficult, or interfere with the smooth running of the strip over the cutting face of the die. By using a concave shear on the punch face, a blank so shaped can be produced, but an appreciable amount of experimenting must be carried out before this can be done with any accuracy.

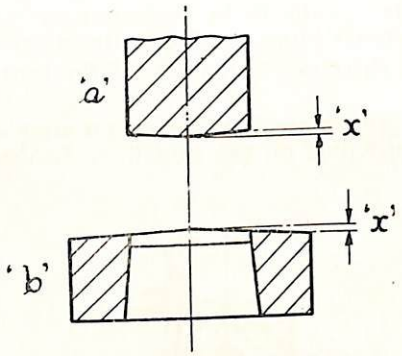


Fig. 2—Shear.

Removal of Slugs or Blanks.

When the hole in the bed of the press is too small to allow the blank to pass through it, or when the spacing of the punches is outside its diameter, it is necessary to provide a slot underneath the die (see Fig. 3) so that the slugs or blanks can be pushed out or removed, either by hand, by an air blast or by other means.

Relying on hand removal of slugs can be dangerous, for if the operator forgets to push them out, they can pile up, forming a solid mass and the tools may fracture.

Using an automatic slug removal device, or an inclined press so that gravity allows the piece to fall away, are considered superior and safer than removal by hand.

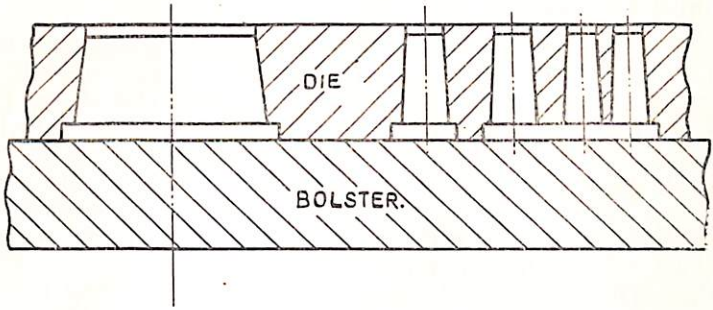


Fig. 3—Slots in Die for Pushing Out Blanks.

Punches Close Together.

When a number of punches must be near each other they should be made stepped as shown in Fig. 4 at "*b*." The step "*x*" should be equal, or less than the material thickness and is used to prevent the punches deflecting.

When using a small punch near to a large one, as at "*a*," the smaller punch should be made shorter so that the smaller hole can be pierced after the metal has been distorted by the larger punch.

To maintain correct centre dimensions between a large punch and a small one very close to it, a good method is to insert a soft steel bush in the hardened large punch and to machine this to take the small punch.

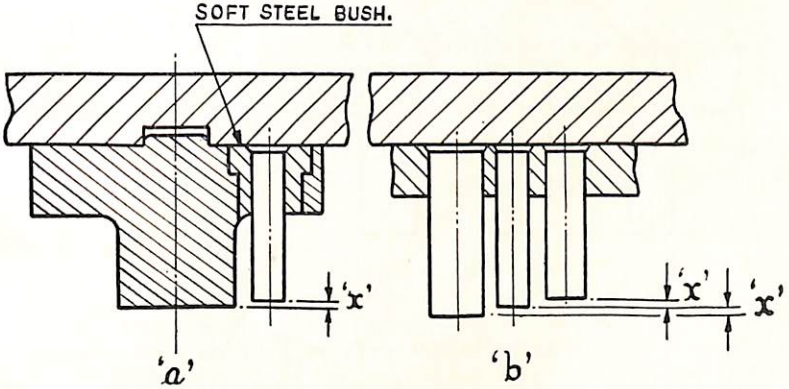


Fig. 4—Punches Close Together.

Securing Punches.

Fig. 5 shows common methods of fixing a punch into the punch plate. The first at "*a*" is a very common method of rivetting the punch over, while "*b*" shows a small shoulder on the punch fitting into a recess. This is considered a much superior design to the former, because it has a firm support against the upward thrust when punching and also holds it firmly when stripping. At "*c*" is shown a hardened steel disc sited behind the punch. This method is used when punching heavy stock, and prevents the punch from sinking into the top plate. At "*d*" a method of holding a slender punch is shown. The outer part is driven into the punch plate and the punch is closely held in it.

The above are meant to be permanent punches, and if one of them breaks it is quite a lengthy job replacing it. Fig. 6 shows various methods of making replaceable punches. At "*a*" is shown a punch held in position by a steel ball forced by a pointed grub screw into an angular recess machined into the punch. A slot is cut into the top of the punch plate to allow the ball to enter and the screw pushes the punch against the hardened disc located in the top plate.

A simpler system is shown at "*b*" where the grub screw forces the punch upwards by pushing against the tapered recess. The spigotted punch at "*c*" is held into the punch plate with cap headed screws. Tool steel can be saved when making large punches by the method shown at "*d*." The punch itself is a spigotted disc screwed into the soft steel backing piece. Die inserts can be held in a similar manner to "*a*" and "*b*."

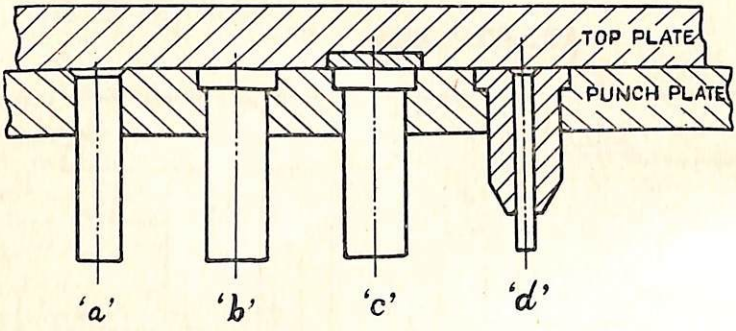


Fig. 5—Methods of Fixing Punches.

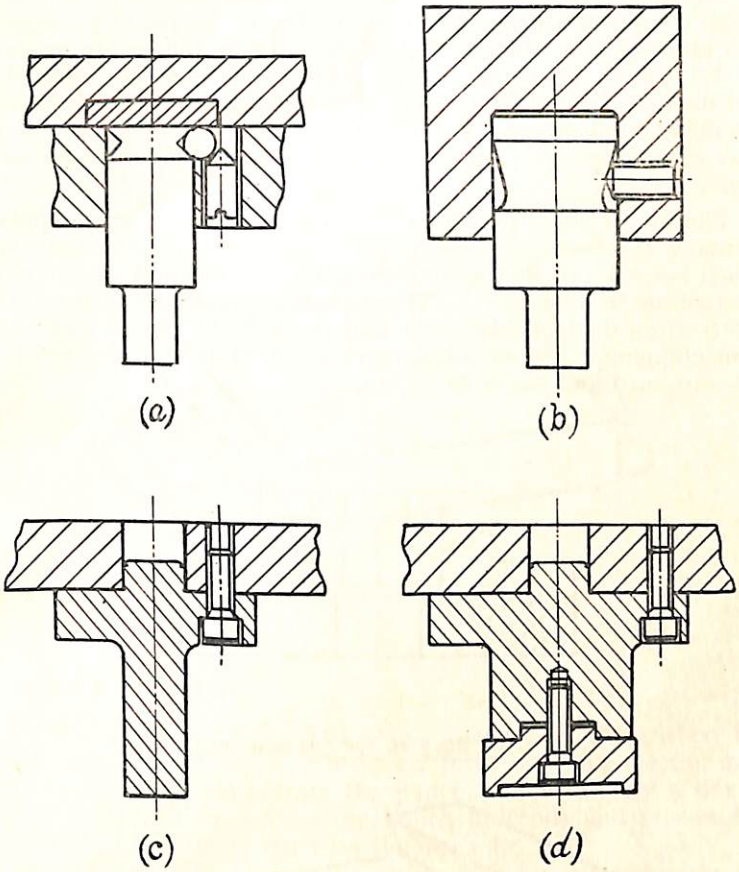


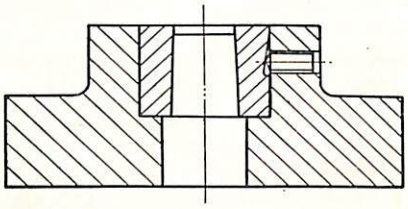
Fig. 6—Removable Punches.

Bolsters.

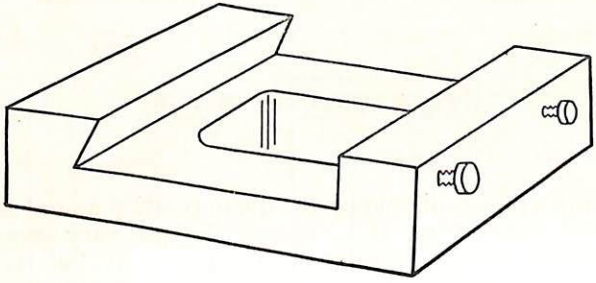
These are a means of holding the die in position and of supplying an adequate support for it. Bolster designs vary greatly, but Fig. 7 shows two types commonly used. At "*a*" is seen a bolster used for securing circular dies of the removable type, whilst at "*b*" is shown a dovetail type for holding larger dies of flat section. This type has the disadvantage of having a large hole to clear varying blank sizes, thereby weakening it, and also the machine screws have a tendency to work loose. An improvement on this type is to have it made with the taper on either side and the die machined to fit it. being held in position by a dowel.

Fig. 8 shows one of the varied types of commercial die-sets which comprises a punch holder and a bolster, aligned by means of two guide pillars running in bushes. These pillars are grooved for lubrication purposes or incorporate oil reservoirs. Punches and dies are fixed on top and bottom members and whilst suitable for many applications, are perhaps particularly useful for short runs when different tools can be secured to the die-set after each run.

The use of guide pillars as illustrated on the die-set is applied to many types of press tools, particularly where more than one punch is used and they ensure that the top and bottom halves of the tool are in alignment. If the press slides are at all worn, the pillars are a distinct advantage and prevent the punches and dies from chipping. Other advantages are that they make the tool self-contained and easier to set up.



'a'- BOLSTER FOR CIRCULAR DIES.



'b'- BOLSTER FOR FLAT DIES.

Fig. 7—Two Types of Bolsters.

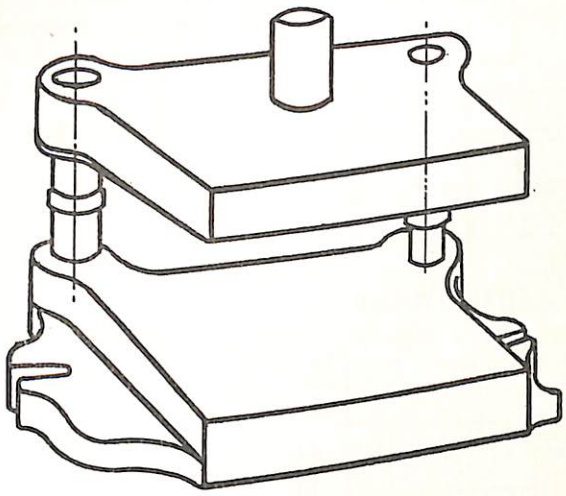


Fig. 8—Commercial Die Set.

Strippers and Ejectors.

A stripper is a plate fixed above the die so that, when the punch ascends, the work is stripped from it. An ejector may serve to strip the work from the punch, but is usually a device that recedes into the die as the punch descends and pushes the blank out of the die aperture on the upstroke.

Fig. 9 shows various types. At *"a"* is the fixed stripper, with the aperture a sliding fit for the punch. The punch at the beginning of its stroke is housed in the stripper and supported by it. The stripper is also an aid when setting the tool. The spring pad type of stripper shown at *"b"* is an essential part of a drawing tool, but is also used for blanking. The pad is set in advance and contacts the strip ahead of the punch, holding the work and keeping it flat while blanking. When the punch ascends, the pad holds the work against the die and strips it off the punch. An advantage over the former stripper is that the operator can see the work until the actual blanking takes place. Stripper bolts retain the pad in position.

At *"c"* is seen a stripper worked by knockout pins, which extend above the punch holder and are an easy fit in the top plate, and rest on top of the stripper plate. These pins are operated

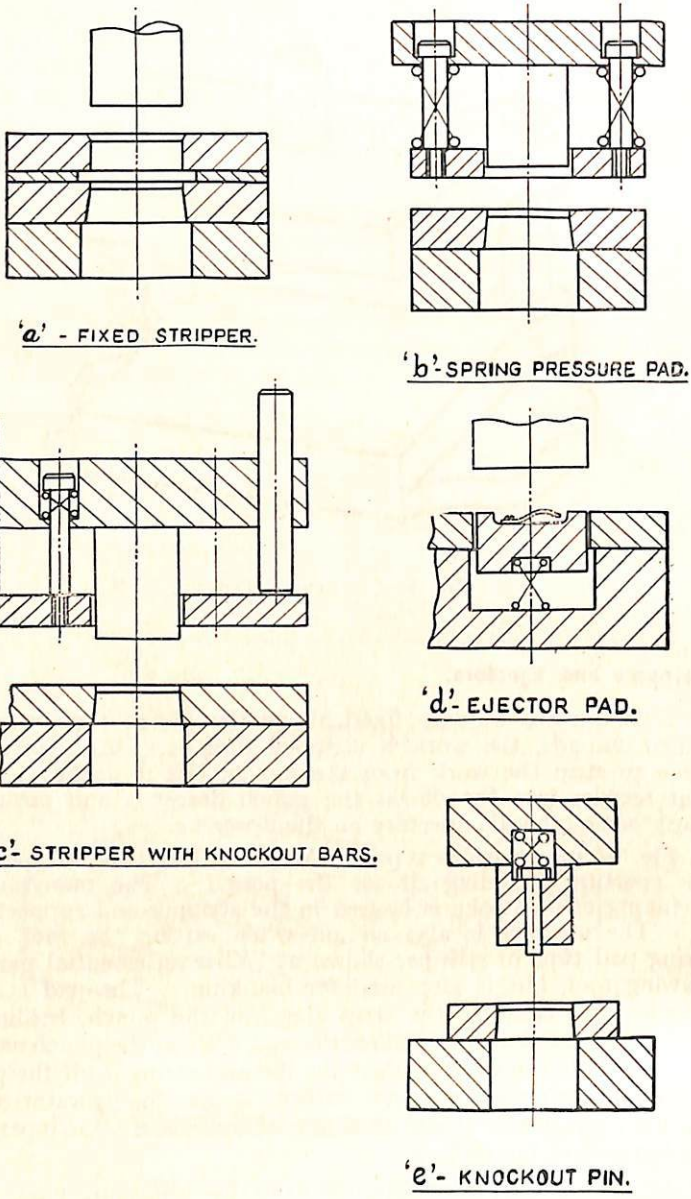


Fig. 9—Pressure Pads and Strippers.

by a knockout bar which is horizontal and fitted between the ram slides, and can be adjusted and fixed to suit the stroke of the tool. A slot in the ram clears this bar and on the upstroke of the tool the knockout bar contacts the pins, and they, together with the stripper plate are forced downwards.

The arrangement at "*c*" differs from "*b*" in that the springs are lighter, and are only used to counteract the weight of the stripper. This type is fitted behind the punch and when the punch wears does not need adjustment. By virtue of being behind the punch, it is easier to set up than the previous spring pad, and does not act as a pressure pad. The pressure pad type is sometimes undesirable, particularly when using a pilot pin designed to centralise the blank strip over the die opening.

At "*d*" is shown an ejector, used when blanking a piece too large to fall through the press bed and when a large hole would weaken the bolster. When the punch descends, the ejector is pushed into the die opening (which has the advantage of having parallel sides) and when the punch returns, the blank is pushed out. The small leaf spring prevents the blank from sticking to the ejector plate.

The knock-off pin shown at "*e*" is used when cutting thin blanks of regular shape which, when using a lubricant, may cling to the ascending punch. The pin normally protrudes by $\frac{1}{4}$" and is held by a light compression spring which allows the pin to be housed inside the punch on the downward stroke.

Stripping Pressure.

The greatest load on the stripper is when the ram is on the upstroke and the material hits the underside of the stripper. A commonly used formula to find the pressure P in pounds is :—

$$P = 4000\ LT$$

when L = length of cut in inches

T = thickness of stock

Shut Height of Press.

This height is defined as the distance measured from the table of the machine to the underside of the ram when the stroke is down, and the adjustment of the ram is as far up as possible. The height of the tool when closed must therefore range between the closed height and the closed height plus the adjustment. Some manufacturers state the shut height to be from the bolster plate rather than from the table, and, therefore, when compiling a capacity list of the various machines, it is necessary to bear this in mind.

CHAPTER 3.

CUTTING DIES.

Blanking means cutting discs or shapes from sheet or strip material, the part so formed being the article required, and piercing means punching holes in the blank, sheet or strip, the slug so formed being scrap.

Cutting dies comprise a large percentage of all the tools used in a press shop, and by means of these tools, products of any desired shape, and parts of intricate design are obtained. Defects in these tools can adversely affect subsequent operations and therefore their manufacture and setting up must be closely watched.

The first consideration in designing a cutting tool is to find the tonnage required.

To Calculate the Blanking Pressure.

A simple formula for calculating the pressure required to blank a round disc is :—

Dia. of disc (in.) × stock thickness (in.) × 80 for steel.

Dia. of disc (in.) × stock thickness (in.) × 65 for brass.

A more accurate formula is :—

Length of cut (in.) × stock thickness (in.) × shear stress (tons per sq. inch).

Shear stresses for various materials are set out in Table 1.

Example.

To blank a disc 3 in. dia. × $\frac{1}{32}$ in. of steel boiler plate, the pressure P would be :—

$$P = 3 \times \pi \times \tfrac{1}{32} \times 30 = 8\tfrac{3}{4} \text{ ton.}$$

Where the shear stress is unknown, use 80% of the tensile stress in tons per sq. in.

To Determine the Capacity of a Press.

To find the tonnage of a single acting press (the type most commonly used) use the following :—

$$(\text{Dia. of Crankshaft at Bearings})^2 \times 3\tfrac{1}{2}.$$

This applies to presses driven from one end of the shaft. For presses driven from both ends the capacity is approximately 50% greater. This rule is well on the safe side for ordinary conditions.

Example.

If the dia. of the crankshaft is 4″, then the capacity of the press is $16 \times 3\frac{1}{2} = 56$ tons.

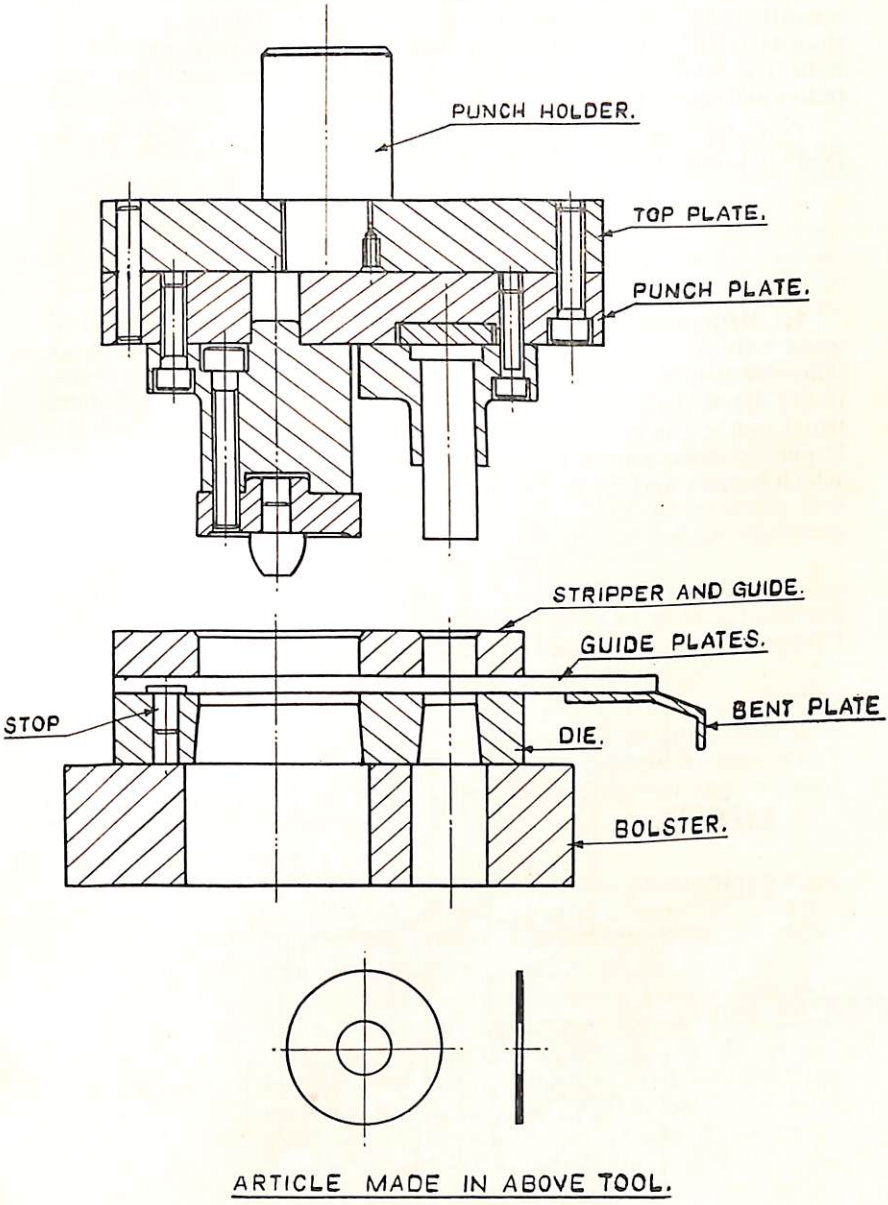


Fig. 10—Follow-on Tool.

It is advisable, after calculating the pressure required for the operation, to select a machine with at least 25% more pressure than that required. Many modern machines incorporate a load indicator which shows the actual pressure being used for each individual operation.

Consider the washer sketched below, Fig. 10. This can be made in a variety of ways, the commonest being :—

1. Using two punches and dies.
2. Using a follow-on tool.
3. Using a combination tool.

1. Using two tools is the simplest method and would be applied when only a small number of washers was required. The large diameter can be blanked first, the blank then located in a recess in the die of the second tool and the smaller hole pierced. A more usual method is to pierce the small hole first and then blank the larger by means of a piloted punch (similar to that in Fig. 10) which locates and centralises the blank.

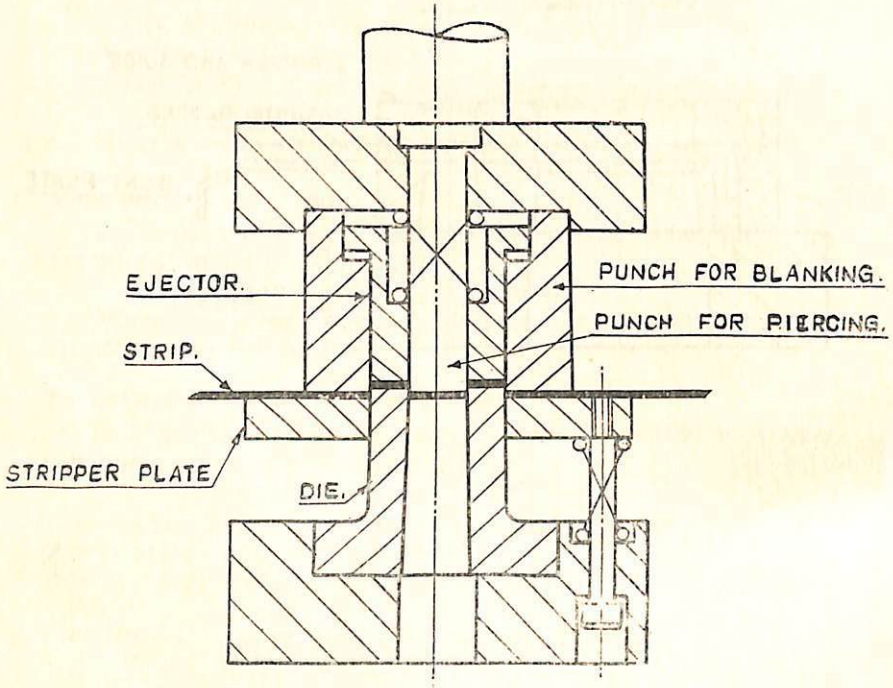


Fig. 11—Combination "Pierce and Blank" Tool.

2. The "follow-on" tool illustrated in Fig. 10 is perhaps the most well known and used method for this type of work. The strip material is fed by hand up to the first sliding stop (Fig. 12) and the small hole pierced. The next step is to withdraw the first sliding stop and advance the strip to the second sliding stop and blank the large hole and thus produce the first washer. Stage three shows the strip further advanced, with the rear of the large blanked hole located against the fixed stop. The ram then descends and the second washer is formed. The stop should be so arranged that the pilot in the large punch draws the strip very slightly away from the stop and centralises it over the large die opening. Should the pilot force the strip against the location stop, the small pierced hole would be distorted or the small punch may break.

The punch assembly is worthy of note. The small punch is driven into a supporting holder whilst a hardened disc prevents the punch from sinking into the punch plate.

The large punch is not made solid, but consists of a small piece of tool steel screwed and spigotted onto a backing piece of softer steel, which has a cushioning effect. The saving in costly tool steel, and the ease with which a broken punch can be replaced, amply justifies the extra machining involved.

The punch holder is securely screwed and locked into the top plate and so positioned between the punches to give a balanced assembly. The stripper plate also serves to guide and support the punches and assists when setting up the tool.

When coiled strip is used, the guide plates are made a sliding fit for the material, but when sheet material is guillotined into strips, it is pushed against one side of the guide plate by means of a flat spring incorporated into the opposite side, so that any variance in strip width can be accommodated.

3. The combination tool (Fig. 11) blanks and pierces the washer with one stroke of the ram. When the tool is open the stripper plate is set level with the top of the die and the strip is fed, either by hand or automatically, between guides over the die face.

The operation is as follows. The blanking punch descends, cutting the outside diameter and depressing the stripper plate, whilst, at the same time, the piercing punch forms the centre hole, the slug falling through the die opening and out through the die bed. On the upward stroke, the stripper clears the strip from the die, being actuated by the springs retained by the stripper bolts and the ejector pushes the blank out of the punch into the strip from which it is removed manually or automatically.

This type of tool can produce concentric work very accurately due to the two punchings being performed simultaneously and also

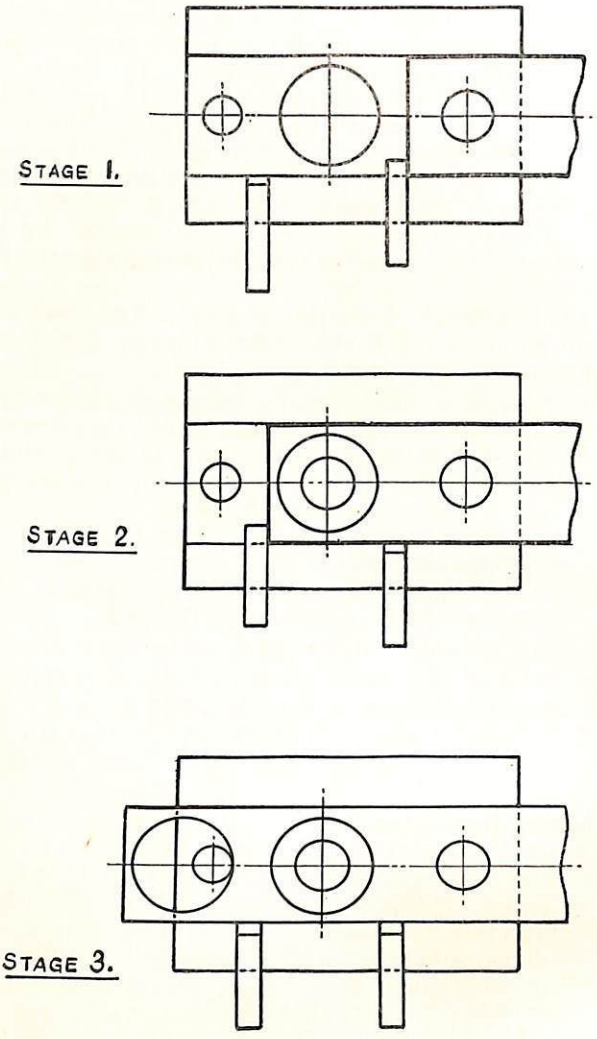


Fig. 12—Layout of Stops in a "Follow On" Tool.

has the advantage of producing flat work at good speed. No difficult milling, shaping or hand work is necessary to produce the tool, all the component parts being circular.

Stops.

The stops illustrated in Fig. 10 and diagramatically in Fig. 12 are known as fixed stops, being either stationary or moved by hand. There are many different forms of stops, some of ingenious design, and are automatic and semi-automatic in operation. The pawl stop of the semi-automatic type (Fig. 13) is used in plain blanking dies and is fitted in a slot in the stripper plate. In operation, the forward motion of the strip raises the pawl against the flat spring and allows the blanked hole to pass over its point. The strip is then drawn slightly backwards, thereby pulling the forward edge of the hole against the locating edge of the pawl and the work is then in position for the next operation. The pawl stop is widely used, is easily made and has the advantage of being visible at all times. The operator quickly becomes familiar with its action and can soon build up to a good working speed.

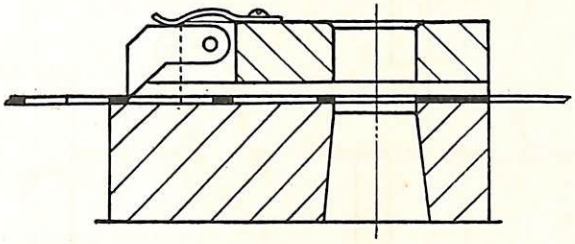


Fig. 13—Semi-Automatic Pawl Stop.

There are many types of fully automatic stops, some working by the downward action of the ram, others being an integral part of the die, whilst patent commercial stops are available. The automatic feeding stop (Fig. 14) is pivotted and attached to the punch plate. An angular slot is machined in the die block upon which the latch slides, pivotting on the pin at the downward stroke of the press. The front edge pushes the strip along until it is in the correct position for the subsequent blanking.

Fig. 14 shows the action diagrammatically and it will be noticed that the latch must be so designed and the stroke carefully adjusted to give the correct lateral motion to the strip. A step is machined at the top which engages the punch plate, thus limiting the backward motion of the latch whilst a small spring holds it in position. In starting the press, the strip is placed under the punch and the

first hole blanked, the hole is then located under the latch and the operation then proceeds automatically.

Another method of strip feeding is by side notching, illustrated in Fig. 15. Here the strip is fed to a step cut into one side of the hardened guide plate and the small hole pierced while, at the same time, the notching or sizing punch cuts a thin strip from the side of the material, making its width equal to dimension "*y*."

This sizing punch is made equal in length to the centre distance "*x*" of the two circular punches.

The strip is then fed along until the rear of the notch locates against the step, and the small pierced hole is then automatically positioned under the large punch.

The sizing punch has a small projection shown at "*s*" which cuts into the strip and ensures that any small fin is removed which would interfere with the smooth passage of the material over the die.

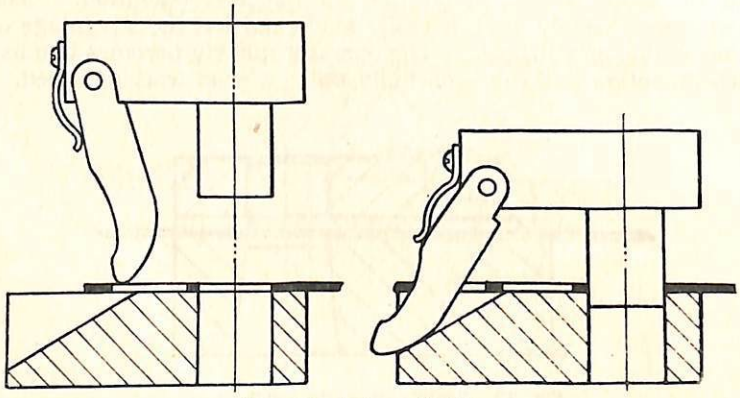


Fig. 14—Automatic Stop.

Strip Layout.

The layout and therefore the width of the strip decides the general design and dimensions of the tool. Economy of material can be effected by careful layout, and typical examples are shown in Fig. 16. The shaded portions in the upper layout indicate two methods of multi-punching and the layout shows how the scrap material is kept to a minimum. Below is sketched another example; here, after the first run through, the strip is turned over and fed through again.

The strip is wider than it would be for a single line of blanks, but it is obvious that an appreciable amount of material is saved. The saving of material by these methods cannot be over-emphasised, and it is often a good plan to cut a number of paper templates and, by manipulating them, so determine the most economical layout.

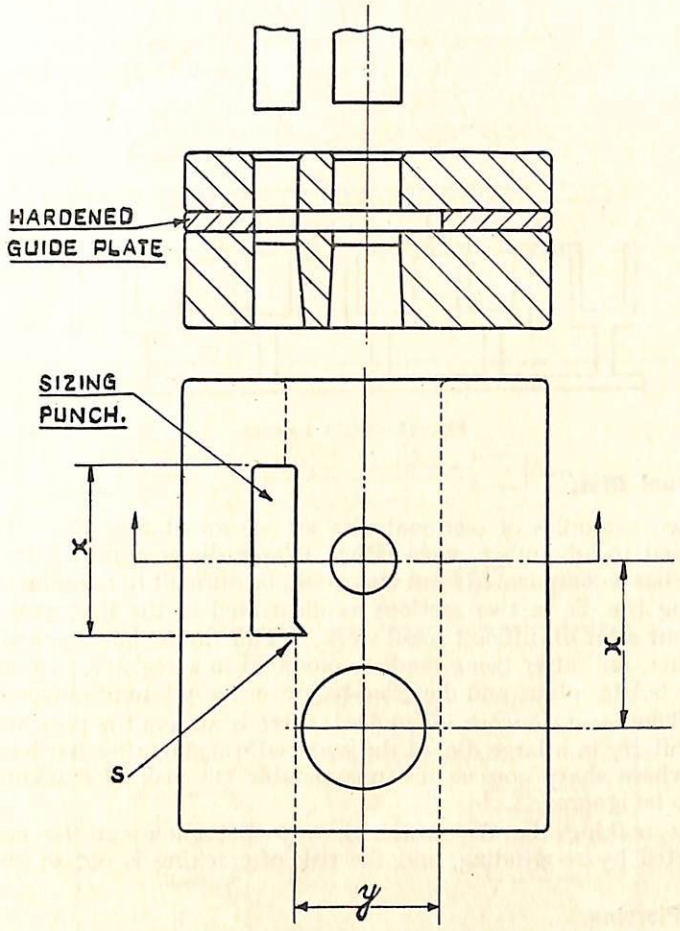


Fig. 15—Side Notching Stop.

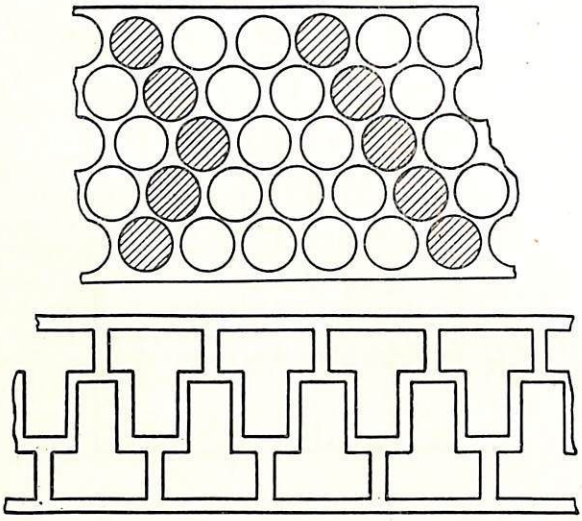


Fig. 16—Strip Layout.

Sectional Dies.

Two examples of sectional dies are shown at Fig. 17. They are used to advantage when either a large die is required, or the blank has a complicated form and would be difficult to manufacture. Making the die in two sections as illustrated in the first example cuts out a lot of difficult hand work. This die is shown spigotted together, and after being made is mounted in a register, machined in the bolster plate, and dowelled to prevent any lateral movement.

When accurate work is required, there is always the possibility, particularly in a large die, of the material warping after hardening, and where sharp corners are unavoidable the risk of cracking is not to be ignored.

By making the die sectional, any distortion can be easily corrected by re-grinding, and the risk of cracking is not so great.

Line Piercing.

For piercing a line of holes in sheet material, the press brake can be used to advantage. Fig. 18 is a practical tool design showing a section through the punch and die and one end of the tool, which can be made to any length depending upon the capacity of the press brake. The tool illustrated is actually nine feet long.

The punches and dies are housed in holders and retained by setscrews. They can vary in diameter and are readily inter-

changeable. The holders are held in dovetailed slots and can be adjusted to any required centre dimension and clamped in position. Each punch is equipped with its own stripper which runs in a tee-slot and individually clamped with square headed bolts. The punch plate and bolster are made in cast iron and the various slots machined on a planing machine. Slots are cored into the bolster for the piercings to drop through and the tool is aligned by guide pillars at each end, which are also adjustable.

The press brake machine is provided with V type bending tools as standard equipment, and some manufacturers also provide an adjustable piercing tool similar to the one shown at Fig. 18.

Any tool design must be carefully thought out, but particularly so in tools of this size, which may cost anything up to £1,000 to manufacture, when its failure to operate successfully would be a serious matter.

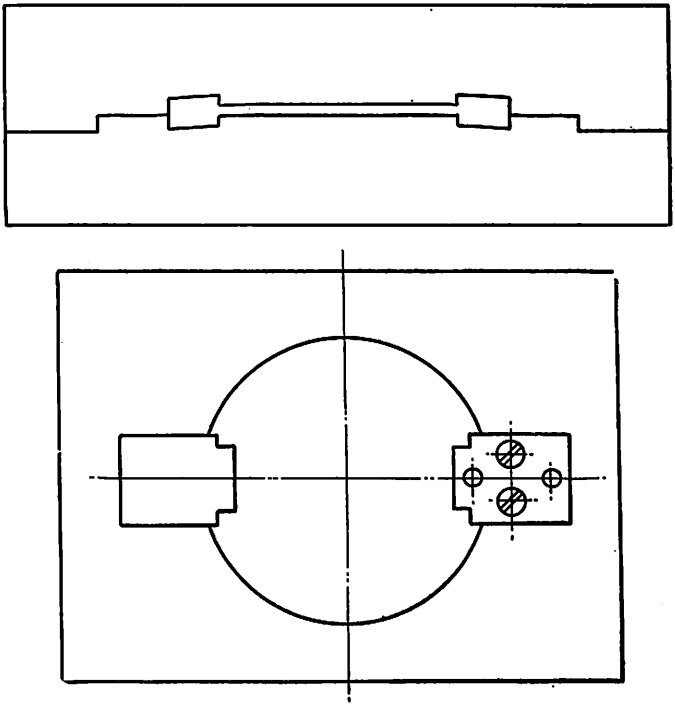


Fig. 17—Dies Made in Sections.

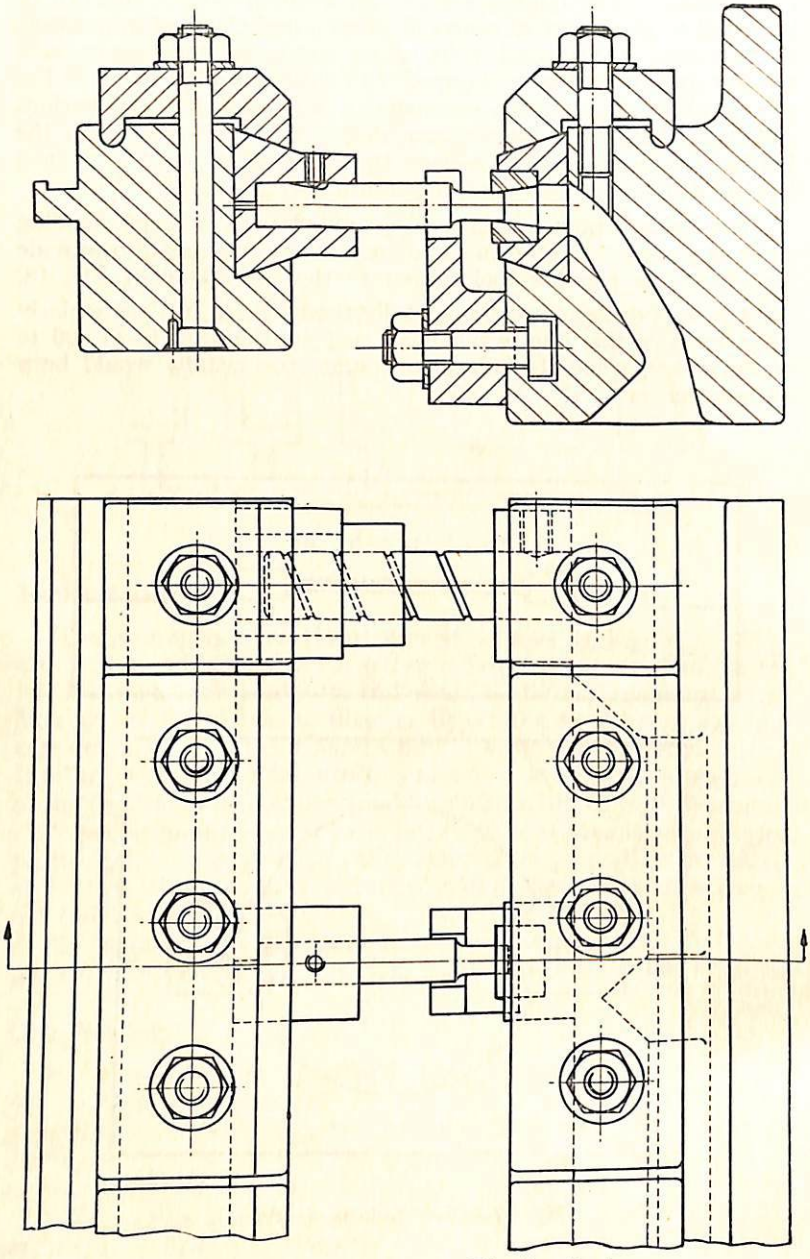


Fig. 18—Adjustable Line Piercing Tool.

Inverted Dies.

A tool layout may at first sight appear impracticable, but a useful tip is to turn the drawing upside down and consider the design as an inverted die, that is, with the punch remaining stationary and the die becoming the moving member (Fig. 19). This type of die is used when the pierced hole must be accurately positioned in relation to the contour of the blank, and also when the blank is too large to fall through an aperture in the die. The diagrammatic sketch (Fig. 19) shows how the die and bolster are made solid, so giving maximum resistance to the downward thrust. The blanks can be ejected by a jet of compressed air, and when the tool is in its open position the stripper bolts hold the stripper level with the top of the die. The relative accuracy of the small holes with the blank is maintained due to the piercing and blanking being done together. The pressure pad in this design slides inside the large die and guides and supports the smaller punches.

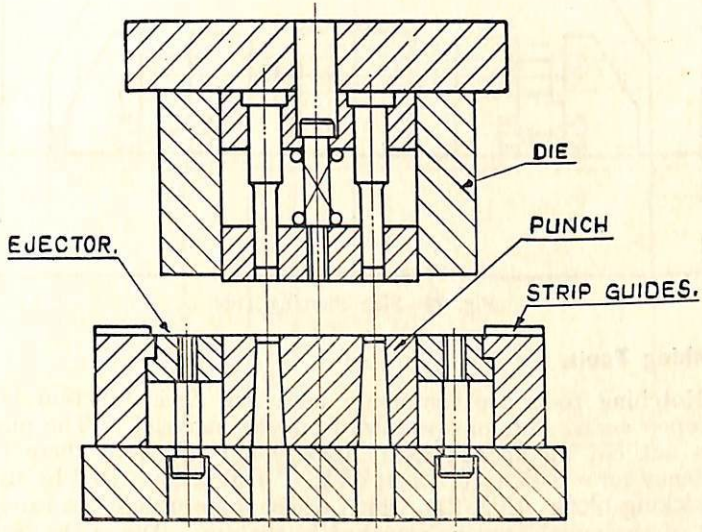


Fig. 19—Inverted Die.

Side Piercing.

An example of side piercing is shown in Fig. 20. Here the pre-formed part is located on the die and the punches are housed in blocks which slide in a tee-slot on the bolster. Their forward motion is controlled by the tapered slides attached to the top plate and guided in the bolster. The tool must be made so that both

punches pierce simultaneously ensuring a balanced end thrust on the die. The punches are guided by stripper blocks which also provide the backward motion of the punches with the aid of compression springs. Instead of the strippers, rubber bushes are sometimes used, being forced over the punches, preceding them slightly and acting as strippers, but this is not recommended because the rubber has to be frequently replaced. The tool is also provided with a pressure pad (not shown) attached to the top plate. It is spring operated and holds the cup whilst the piercing is being done.

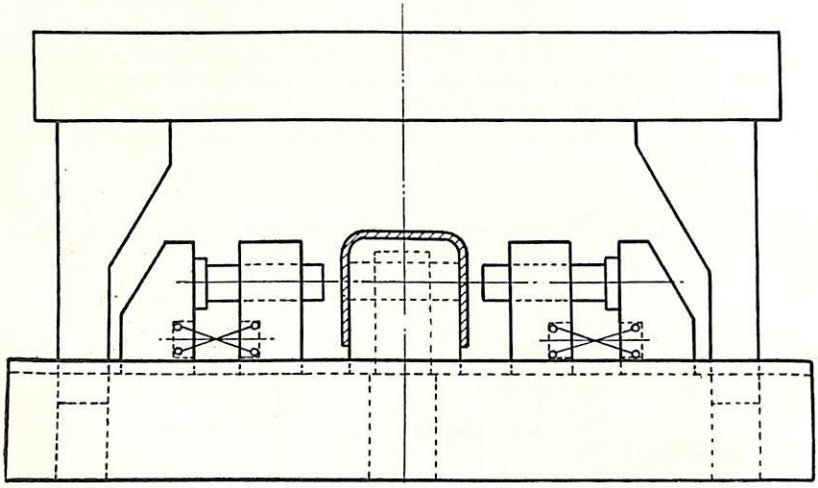


Fig. 20—Side Piercing Tool.

Notching Tools.

Notching tools are commonly used and their function is to cut open ended slots or apertures from the material. The punch does not cut all around its periphery and therefore there is a tendency for a backward thrust on it. This is countered by using a "kicking block" (Fig. 21), which whilst more usually an integral part of the punch, can be attached to the die. When the punch descends the kicking block engages the punch before the cutting edge comes into operation, and when cutting does take place prevents the kicking or backward thrust. The kicking block may also be designed to act as a location for the work, for usually notching presses have a very short stroke and the punch is always engaged in the die.

An adjustable notching die is usually found in the press shop and may be made in many ways. The one illustrated (Fig. 22)

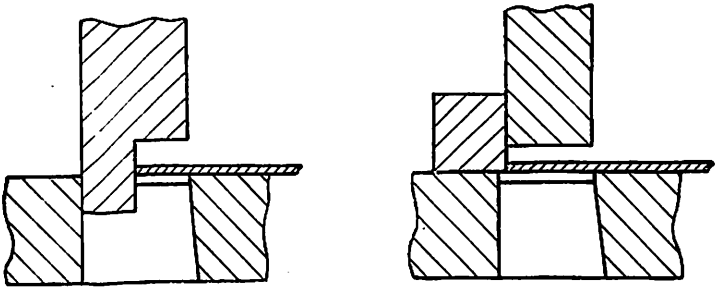


Fig. 21—Examples of Kicking Blocks.

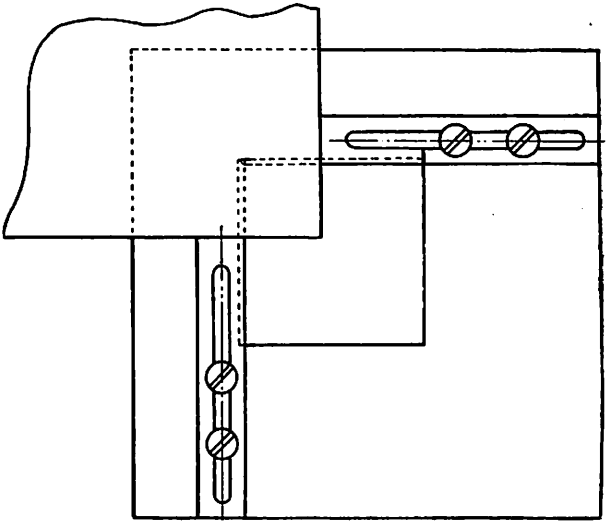


Fig. 22—Adjustable Notching Die.

is used for notching various sizes of square corners in sheets prior to their edges being formed. The slotted bars are adjustable, and thus the varying sized notches are obtained.

Cropping.

Cropping usually means cutting off lengths of strip, and most press shops are equipped with an adjustable cropping tool which cuts off pieces of varying lengths.

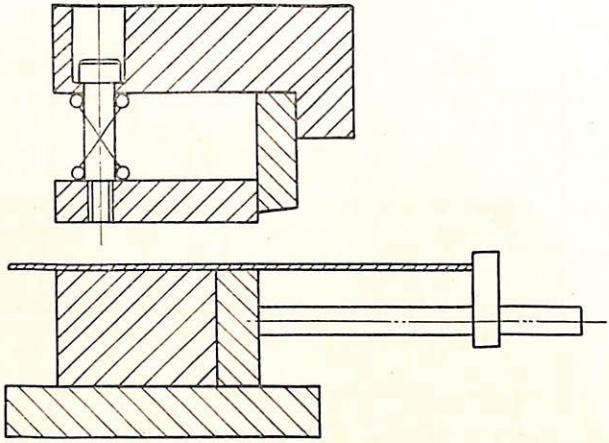


Fig. 23—Adjustable Cropping Tool.

Fig. 23 shows such a tool in diagrammatic form and it will be seen that it is similar in operation to a guillotine having two blades, the lower being fixed and the upper moving. The ram is equipped with a blank holder set just in advance of the punch, and holds the material while the cropping takes place. Attached to the bottom tool is an adjustable stop which regulates the length of material cut.

Chapter 4.

BENDING AND FORMING.

Bending dies are used for forming flat sheet or wire into various forms. The action is to force the material into female cavities in the die by means of the male shaped punch.

General Principles.

The radius at the bottom of the bend should be made as large as possible to eliminate surface cracks and the material should be bent at right angles to the direction in which it has been rolled wherever possible.

It will be seen that the material will follow the line of least resistance when bending. Fig. 24 illustrates this principle and shows a double vee tool, open at "*a*" and half closed at "*b*", where the centre of the punch starts the bend and takes the material down

until the raised part of the die forces the material back into the punch form.

The material follows the profile of the punch rather than the die (Fig. 25). At "*a*" the tool is shown open and closed at "*b*," where it is seen that the material has formed around the top former and it is not necessary to work out the profile of the bottom tool.

As no edge stress is involved in forming as in blanking, the material used for the manufacture of the dies need not be tool steel, but may be made from mild steel and case hardened. The tools should be tried out in their soft state and any adjustments made before the tool is hardened.

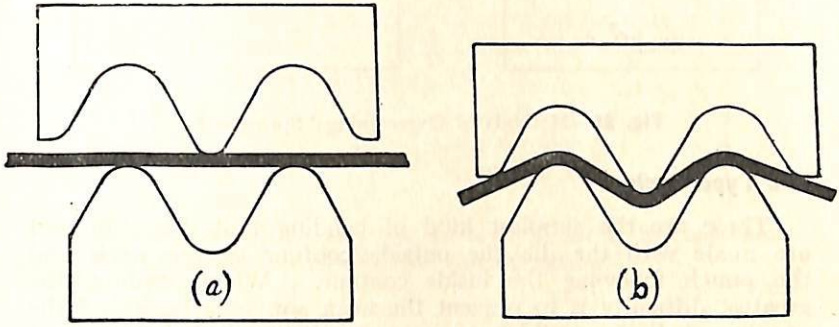


Fig. 24—Work Follows Line of Least Resistance.

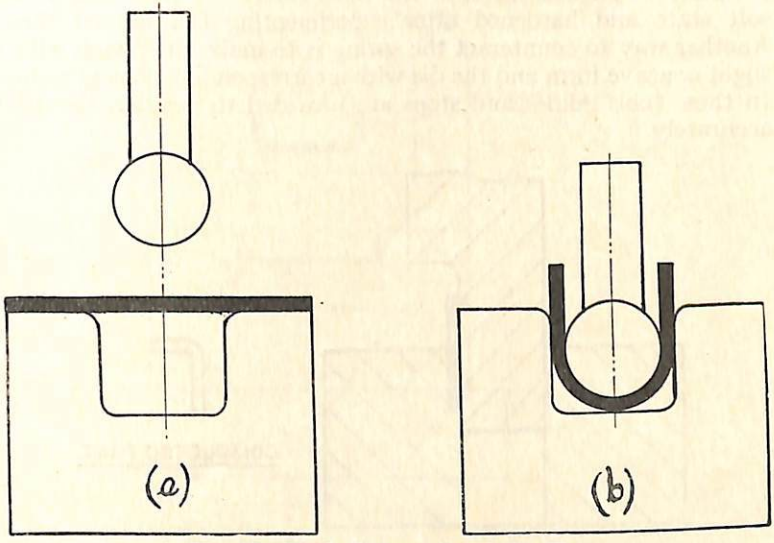


Fig. 25—Work Follows Punch Profile.

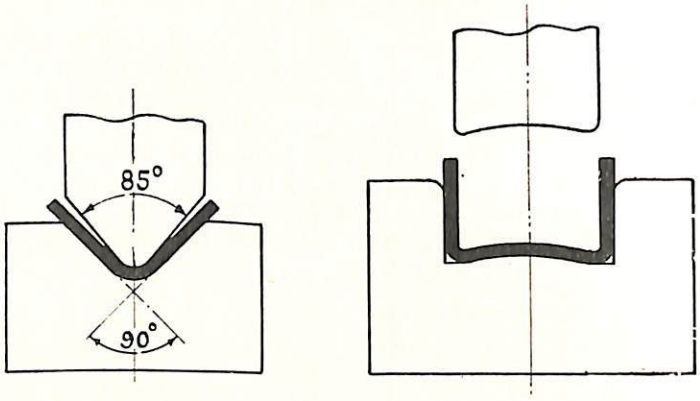


Fig. 26—Methods of Overcoming "Springback."

Vee Type Tools.

These are the simplest kind of bending tool (Fig. 26) and are made with the die the outside contour of the work and the punch following the inside contour. When bending, the greatest difficulty is to prevent the work springing back and the punch and die for a 90° bend is made with an included angle of 85° on the punch, to give a definite set to the work. Where accuracy of angle is needed, the tools should be tried out in the soft state and hardened after experimenting has proved them. Another way to counteract the spring is to make the punch with a slight concave form and the die with a corresponding convex radius. In these tools guides and stops are provided to position the work accurately.

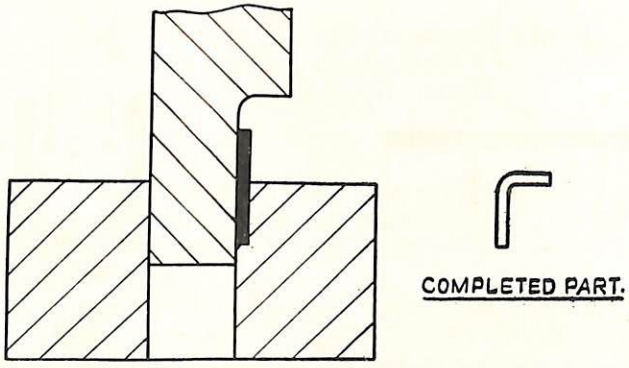


Fig. 27—Tool for Forming Accurate Bend.

A method of forming a more accurate bend is shown at Fig. 27.

Here the work is dropped onto a ledge in the bottom former, the depth of which corresponds to the length of the downward leg of the component. As the punch descends, the radius on it pushes the work over and bends and flattens it on the die block. The completed form is shown on the right. One advantage of this type of tool is that two components cannot be inserted at once, as occasionally happens in the more open type of tool, often resulting in a fractured die.

To Calculate the Bending Pressure.

For a straightforward bend a good working formula is :—
Length of bend (in.) × stock thickness (in.) × bending factor.

The commonest bending factors are :—

Mild Steel ...	... 10	Hard Brass	... 8
Harder Steel	... 20	Soft Copper	... 6
Soft Brass ...	... 6	Hard Copper	... 8
Aluminium	... 6		

Here, as in blanking, a press with 25% more tonnage than that calculated should be used for the operation.

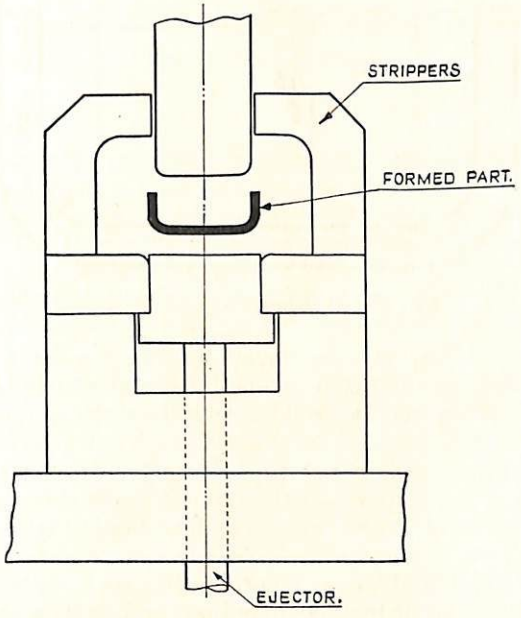


Fig. 28—Channel Bending Tool.

Channel Forming Tools.

In these tools (Fig. 28) the punch is made slightly less than the inner form of the work and the corners on the punch should have a radius increasing as the thickness of the stock increases. A spring pad is used on this tool and is so arranged that it lies level with the top of the die forming a flat surface for the material to rest upon when the tool is open. When the punch descends it engages the work and pushes it, together with the spring pad, through the die, and throws up the side pieces. The spring pad "bottoms" at the end of the stroke ensuring a flat bottom on the formed part.

On the up-stroke the spring pad carries the work up until the pad is level with the top of the die and the strippers then remove the work from the punch.

The developed length of the material to be bent can be calculated by the formula $3{\cdot}14\ (r + \frac{1}{3}\ t) + x + 2y$ (see Fig. 29) giving a close approximate length.

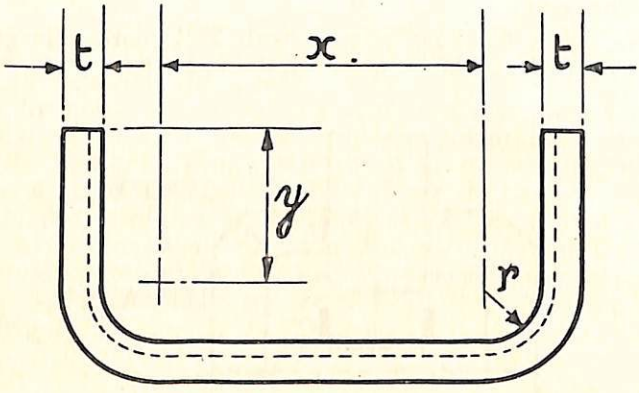


Fig. 29—Development Calculation.

When calculating the developed length of a bent piece, the neutral bending line is taken as one-third material thickness from inside bends when bending mild steel across the grain in V type bending tools.

When using a spring pad type of tool (Fig. 30) the neutral bending line is taken at one-fifth material thickness when bending across the grain and also when bending harder steels in either type of tool.

For the softer and more ductile metals such as brass, copper and aluminium, the neutral bending line can be taken at the centre line when radius "*r*" exceeds twice the material thickness.

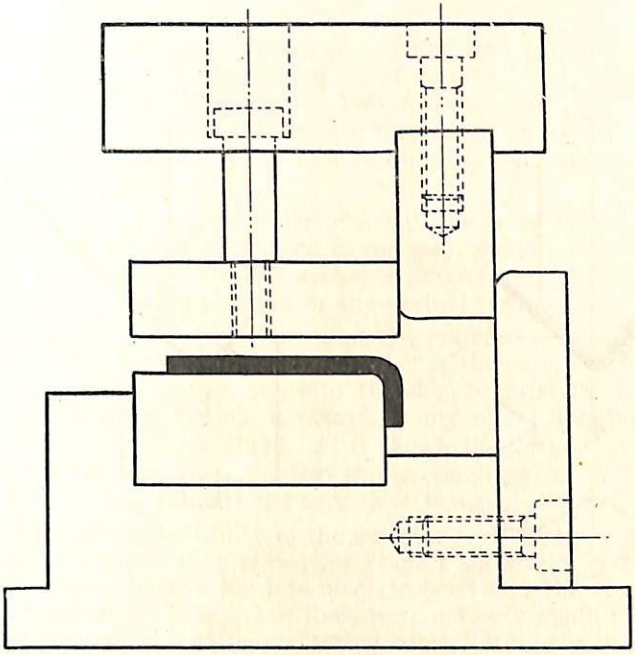


Fig. 30—Side Bending.

Side Bending.

This type of tool (Fig. 30) is more complicated than the commoner vee tool, but gives a more accurate bend. The work is pushed up against the guide plate, which determines the length of the bent leg. On the down stroke, the pressure pad holds the work against the die whilst the punch forms the bend. The guide plate prevents the punch "kicking" and also helps the top former to iron the material, against the die, thus preventing the springing back.

When accurate length of leg is required, these pressure pad type of bending tools have the disadvantage of tending to drag the material over the die surface, when bending takes place. This is due to there not being sufficient spring tension on the pressure pad and this can only be corrected by increasing the tension until by experiment, the length of leg is to the required dimension.

Strip or sheet metal should always be bent across the grain of the material rather than along it. The direction of the grain is produced in the rolling process and by bending across it there is less tendency for the material to crack.

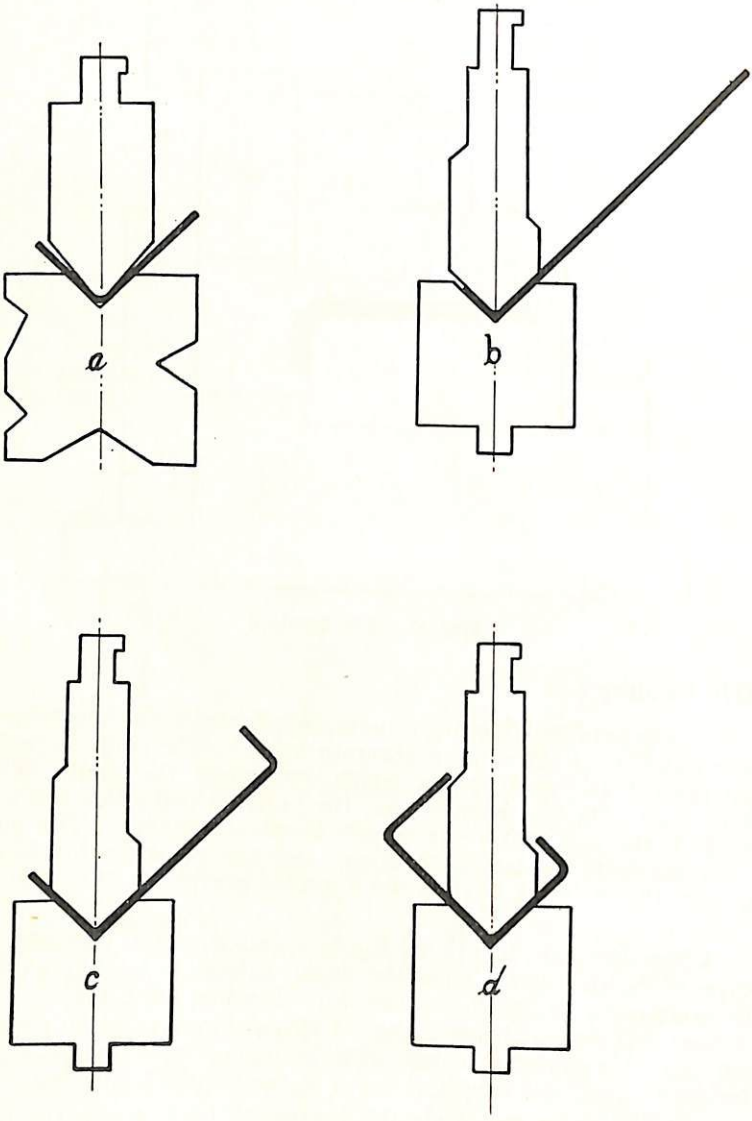


Fig. 31—Press Brake Tools.

Press Brake Tools.

The press brake can be used for cutting and piercing, but is mainly used for bending long lengths of material, and can handle material up to fifteen feet long. Two operators usually work the machine together and many intricate shapes can be formed on the simplest of tools. Fig. 31 shows sections through typical press brake tools.

Two tools are used, the lower or female die being bolted to the bed, the upper die being attached to the ram, which moves up and down at the rate of 20 to 30 strokes a minute. The foot pedal can be utilised to stop the ram in any desired position.

Stops are provided to ensure that the material is bent parallel with the tools along its length. At *"a"* is shown a vee bending tool, with various angles cut into the die, to produce different shaped bends when the die is placed in any of its four positions on the bed. At *"b"* *"c"* and *"d"* is shown the various stages in forming the three bends in the part shown completed at *"d."* The punch is cut away to clear the successive bends.

An example of the utility of the machine is depicted at Fig. 32, where a sheet metal tube is bent. Stage 1 shows the ends being bent up, stage 2 shows the intermediate bend and the completed form at stage 3. These three tools were actually made nine feet long and were used for manufacturing tubes during the war when they were in short supply.

Cutting Off and Bending.

Many ingenious combination tools can be made that include bending and forming with other operations such as stamping, blanking and piercing. Fig. 33 shows a tool used for cutting to length and bending a channel form. The developed length of the material must first of all be ascertained by experiment before the punch size is finalised. The material is fed to a stop and the punch descends and cuts the material to length over the two die blocks, the length *"a"* in each cutting being scrap. After cutting, the inner part of the punch forms the bent component over the lower forming die. As the punch ascends, the work is retained in it, and is ejected by means of the knockout bar working inside the punch.

Cam Forming.

Examples of cam forming are shown at Fig. 34 and 35.

Fig. 34 shows a troublesome form being bent in one operation. These forms are frequently required in large quantities and the tool illustrated is simple and inexpensive. The top diagram

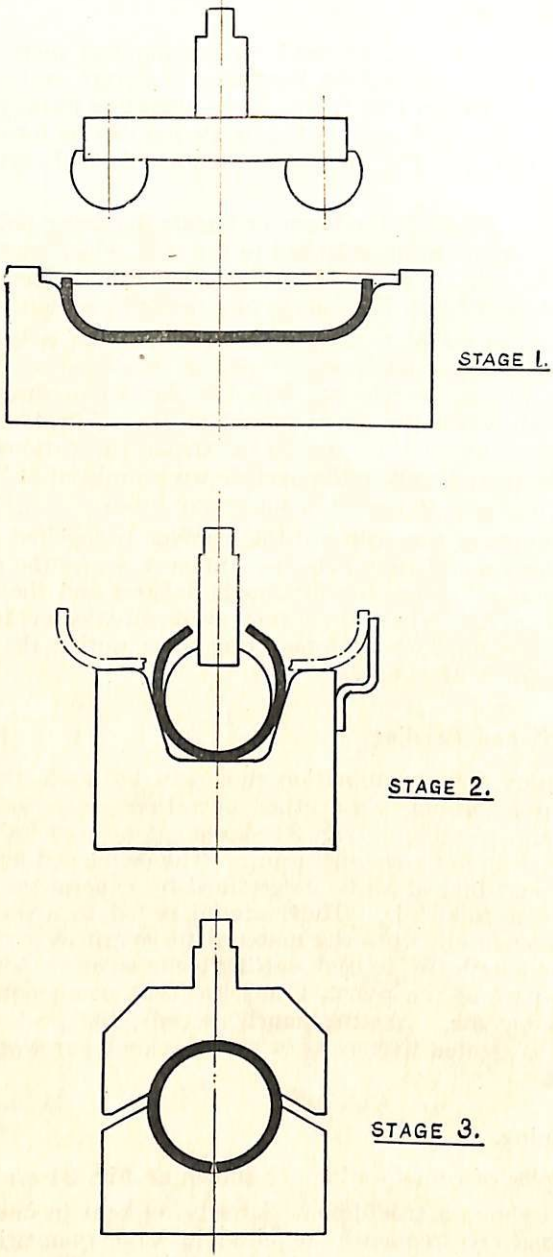


Fig. 32—Tools for Forming Tubes.

shows the tool open and the dies raised by means of the spring bar housed in the bolster, and the dies so arranged that they support the work. Below, the tool is shown closed and the part formed, with the spring bar being depressed. On the up-stroke this bar acts as an ejector. Fig. 35 shows an interesting design for forming a difficult bend. The swinging arm pivoted in the punch and carrying a pivoted roller bends the material down until the travel is checked by the die. The arm then swings to the left and continues until the part is completely formed as shown in black in the illustration.

Cam operated dies have many applications including bending acute angles on more than one side at once.

Coining and Embossing.

Coining is largely confined to the production of coins, keys and badges, and small components in general. The operation is essentially forcing the metal to flow whilst cold and is usually carried out in enclosed dies. Pressures of more than 100 tons per sq. in. are frequently used so that the impressions obtained are sharp and clear. Care must be taken particularly when closed dies are used to ensure that only the correct gauge of metal is used,

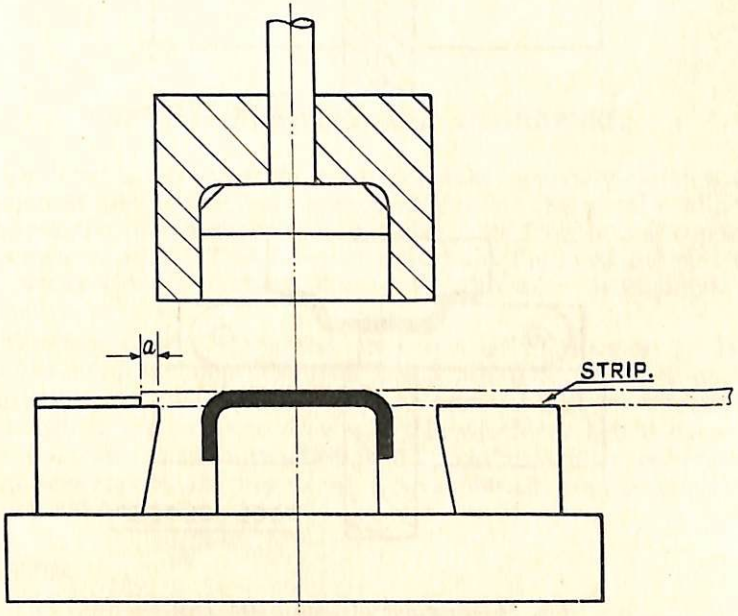


Fig. 33—Cutting Off and Bending.

otherwise a fracture of the tool will occur, because of the high pressures necessary for this operation.

Embossing is the production of designs in relief, and the material remains at the same thickness throughout the operation. There are two types of embossing, open and closed. In the open type the form is cut in the punch and only light pressure is used, the material taking the form of the punch. In closed embossing, where more complicated forms are required, the top and bottom tools are both formed to the contour of the part to be made.

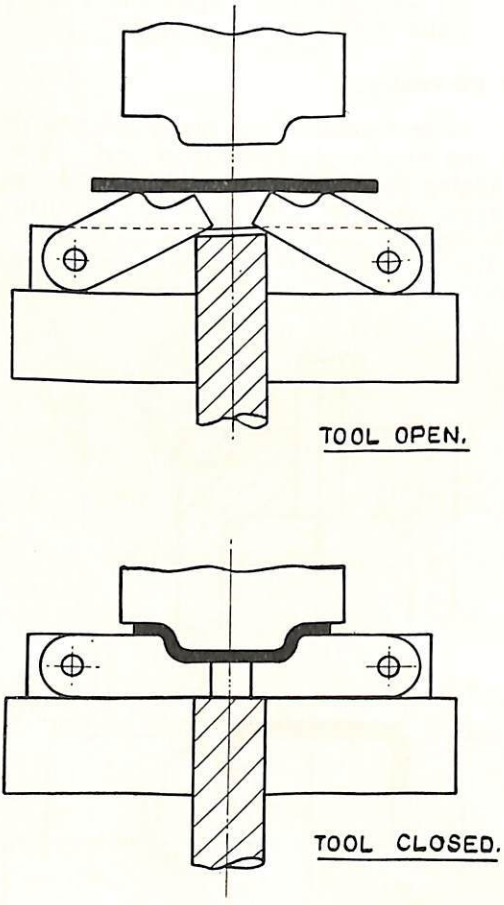


Fig. 34—Example of Cam Form Tool.

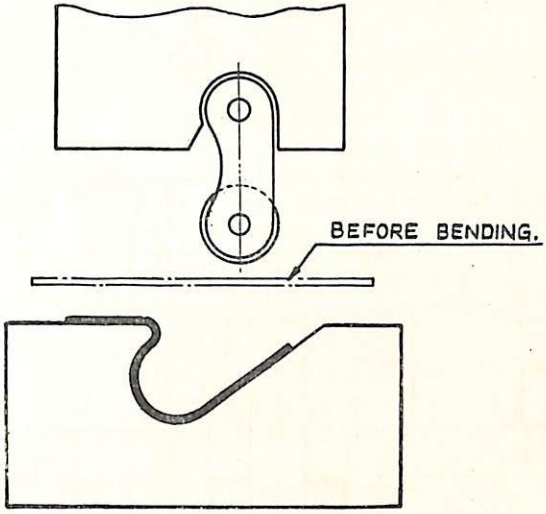


Fig. 35—Example of Cam Form Tool.

CHAPTER 5.

CUPPING, DRAWING AND REDRAWING.

Drawing is the operation in which blanks, generally cylindrical, are forced into a cavity of required shape, and the metal confined between the tool surfaces so as to change its form into a cupped or similar shape. This function is perhaps the most difficult of all pressworking operations due to the difficulty of eliminating excessive wrinkles.

Cupping is usually carried out previous to drawing. The number of draws depends upon the depth the cup must be in relation to its diameter, the type of material and its thickness. Although it is possible to draw a cup in which the height exceeds the diameter, modern practice is to perform smaller reductions at greater speeds, and not to risk a breakdown caused by effecting an excessive draw.

Cupping.

The simplest drawing operation is forming a very shallow cup which involves no reduction in the thickness of the metal, but

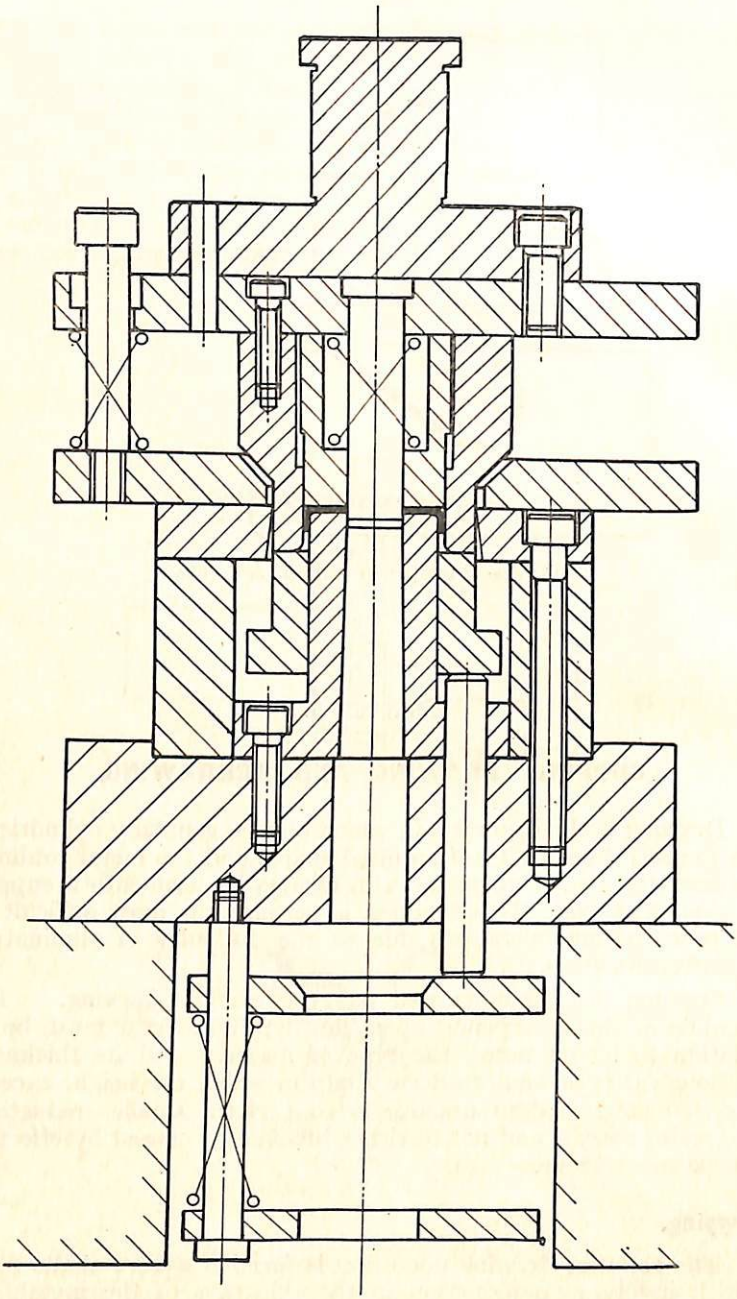


Fig. 36—Compound Blanking Cupping and Piercing Die.

consists of folding the metal uniformly all around and tends to thicken it at the open end.

Fig. 36 shows a combination tool which blanks, cups and pierces at the one operation. The strip material is fed through guides over the die face and on the downward stroke of the ram, the large pressure pad holds the material in position while the blanking punch follows, cutting the disc and forming it into a cup shape over the die. The inner punch then follows piercing the centre hole, the punch ejector preceding the punch and the blanking punch pushing down the ejector.

On the upward stroke, the ejector pushes the cup off the die, being worked by three spring operated pins, the springs of which are housed in the opening in the bed of the press. The piercing falls straight through the tool and through the press bed.

The punch ejector is forced downwards by a large spring and ensures that the formed part does not adhere to either the blanking or piercing punches.

Fig. 37 shows an example of a flanged cup form. Here the disc has been blanked previously and is located in a recess in the ejector plate, which lies flat with the bottom former when the tool is open.

On the up-stroke, ejection is carried out by means of a large rubber pad which pushes three pins and the ejector above them, over the lower die.

To ensure that the cup is not retained in the top former, the ejector working inside it is operated by a positive knockout rod.

Principles of Drawing.

The essentials of a drawing die (Fig. 38) are a punch, a die and a pressure pad. The upper part of the illustration shows the pressure pad holding the material just before the punch starts to form. An air hole through the punch prevents a vacuum forming when stripping the work off it.

The lower illustration shows the cup partly formed. On a mechanical press, the pressure pad is controlled by stripper bolts, the lower the ram descends the greater the pressure exerted by the pad. This has the disadvantage in deep drawing of often tearing the material at the die radius. The hydraulic press, on the other hand, gives a more constant and therefore more efficient action to the pressure pad.

As the ram descends, the pressure pad holds the blank in its correct position on top of the die before the punch begins its stroke.

The stresses set up in the material are varied. The material at the bottom of the cup does not change in thickness as it travels

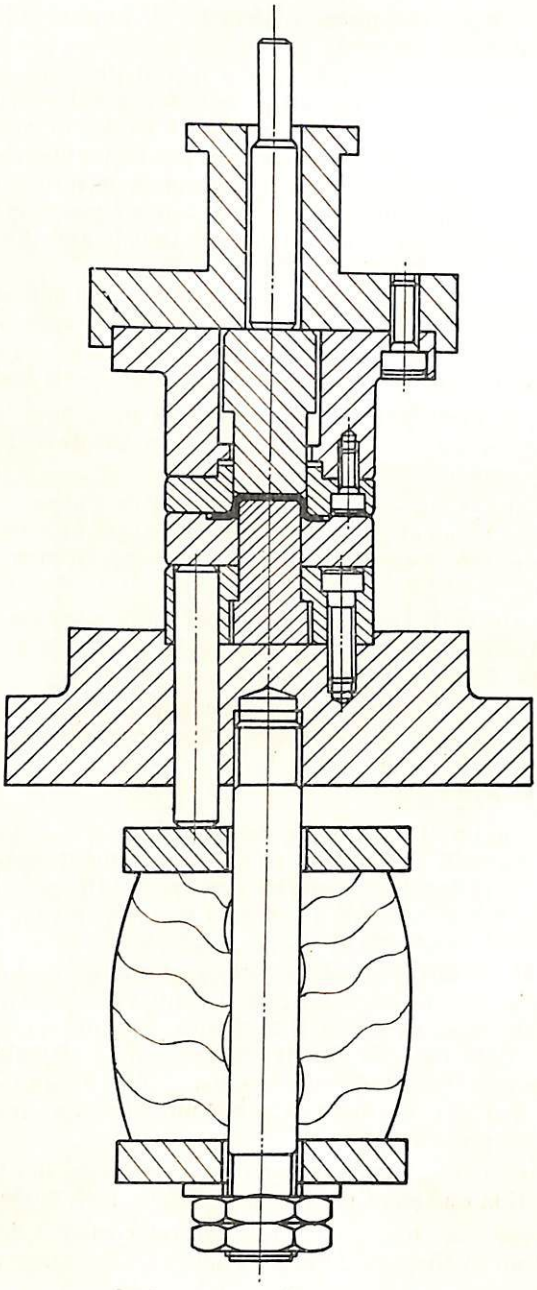


Fig. 37—Cupping Tool.

through the die, but at the edge of the blank the stresses are compressive and an increase in metal thickness takes place here due to the metal crowding itself into a lesser diameter. In the walls of the cup the stress is tensile owing to the punch stretching the material.

The gradual thickening of the metal at the periphery and the increasing pressure exerted by the pressure pad, increases the tension on the sides of the cup through the punch, so that a fracture may occur in the material. A taper on the die surface of 2° to 8° decreases this pressure and allows the material to flow over the die face more readily. When it is necessary for the depth of draw to exceed the diameter of the shell, an efficient method of obviating fractures is to machine a step, ·003″ deep, on the punch at a height of slightly less than the cup's diameter from its nose. This step bites into the metal and relieves the working stresses at the critical point.

Stripping from the Die.

A simple way to strip the work is shown at Fig. 39. Here the cup is drawn right through the die and, when clear, opens out very slightly and, as the punch ascends, this open edge catches against the lower die surface and the work is stripped from the punch.

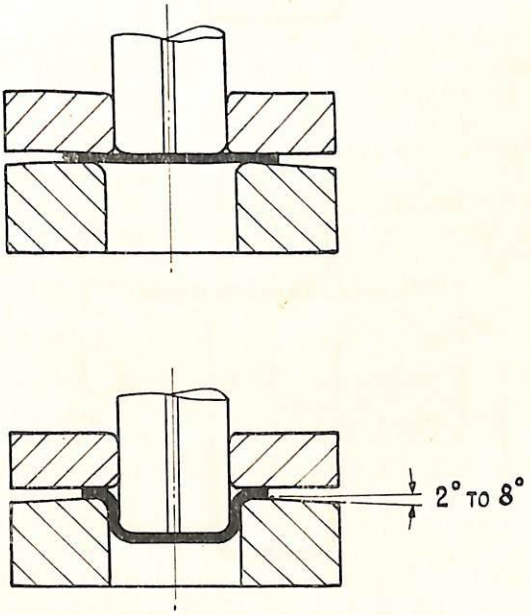


Fig. 38—Essentials of a Drawing Tool.

Another method is to machine a groove in the bolster to take a spring ring. As the work and punch pass through it, the ring opens, but on the return stroke the cup opens out and catches the underside of the ring and is stripped from the punch.

This illustration shows the type of die used for drawing a cup made from thicker material, where no pressure pad is used. The cup diameter should not exceed twenty times the material thickness, the material being robust enough to overcome any wrinkling.

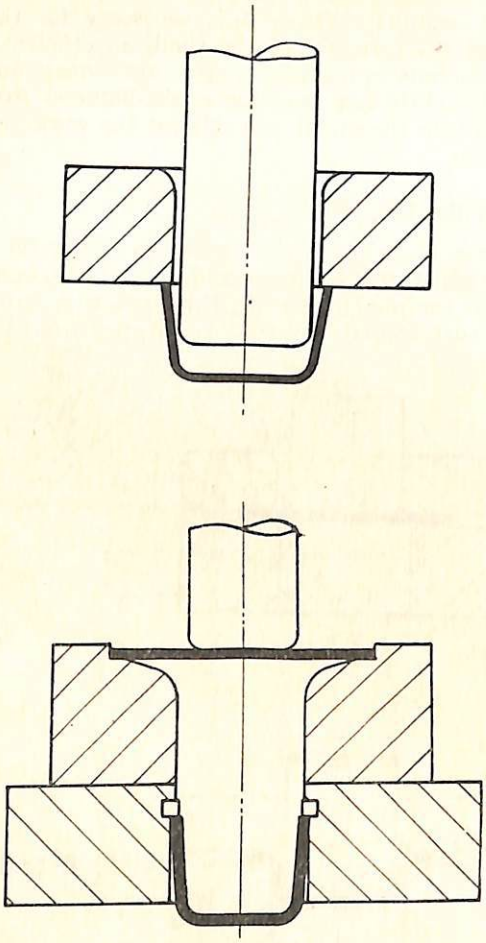


Fig. 39—Stripping Drawn Work.

Calculating the Blank Size.

The usual formula for calculating the diameter of the blank for forming a cup is :—

$$D = \sqrt{d^2 + 4d\ (L - 0{\cdot}43r)}$$

where d = diameter of cup (inside).
L = depth of cup (inside).
r = inside corner radius.

For other blank formulae see Tables 2 and 3.

The radius over the edge of the drawing die is very important.

If the radius is too small the material will tend to rupture, and if too large wrinkles will form.

Ideal radii have been found by experience to be :—

For $\frac{1}{64}$" material use $\frac{1}{16}$" radius
For $\frac{1}{32}$" material use $\frac{1}{8}$" radius.
For $\frac{1}{16}$" material use $\frac{1}{4}$" radius.
For $\frac{3}{32}$" material use $\frac{7}{16}$" radius.
For $\frac{1}{8}$" material use $\frac{9}{16}$" radius.

The radius on the punch should be as large as possible particularly when the shell has to be redrawn.

Wrinkles.

There are two types of wrinkles encountered in drawing. One is the wrinkle formed when the blank leaves the pressure pad and rides over the die radius. These are usually known as "body wrinkles" to differentiate from the "flange wrinkles," which occur when there is insufficient pressure between the pressure pad and the die. Thicker metals of $\frac{3}{32}$" upwards are usually drawn without using a pressure pad, because the material offers sufficient resistance to wrinkling, but when drawing thin gauge metal a pressure pad must be used for wrinkles are more liable to form particularly when the blank is of large diameter.

Methods of Drawing.

There are four usual methods of performing the drawing operation. The first and most widely used is to use the single acting press and the type of tool illustrated in Fig. 38.

The second method employing a double-acting press is shown at Fig. 40. Here a deeper cup can be drawn than on the single acting press, and the two punches A and B are separately mounted on individual rams. The outer punch A descends first, cutting the blank and then acting as a pressure pad, holding the blank against the die while the inner punch descends, forming the cup and drawing it right through the die.

The third method is the combination tool, used on a single-acting press, and is illustrated at Fig. 36.

Frequently the press used is of the inclinable type, so that the drawn cups fall away by gravity. The fourth method is not so widely used and involves the use of a triple-acting press. Here blanking, cupping and embossing or stamping is carried out at one operation, which is similar to that of the double-acting press, but here the inner punch carries the work down onto a punch moving upwards and carrying the embossing form, so that the bottom of the cup is squeezed between the two punches working in opposite directions.

The type of tool to use depends upon the form of the finished article. A shallow cup form lends itself to the combination type tool whilst a deeper cup would be drawn on a double-acting press.

Again, if only a limited quantity of parts are needed, two simple tools would be used, the first a blanking tool and the second a simple push-through drawing die.

Reducing the Diameter.

The number of drawing operations must first of all be split up and the percentage of reduction calculated.

A shell of, say, 3·15″ dia. produced from a blank 10″ dia. would need three operations, and the usual reductions expressed in percentage form are 40%, 25% and 15%.

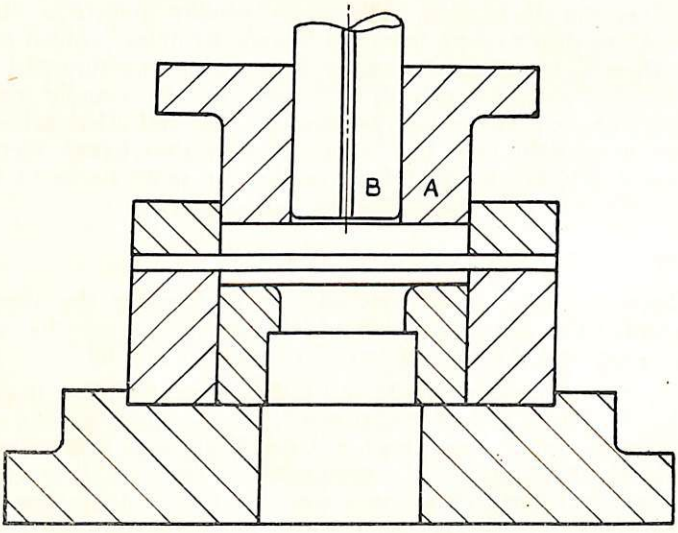


Fig. 40—Drawing on a Double Acting Press.

Therefore, the first draw would be from the 10″ blank to 6″ dia., a 40% reduction, the second from 6″ to 4½″ dia., and lastly, from 4½″ to 3·15″ dia.

Although the type of material largely governs the percentage reductions and no specific rule applies, the above example can be taken as a general guide.

Redrawing.

The shell should be annealed before being redrawn to remove the working stresses. The thickness of the walls of the material is "ironed" and made less, the drawing space between the punch and die being made less than the original thickness of the material.

The bottom thickness remains unchanged. It should be noted that in manufacture both the punch and die should be polished in the direction of the flow of the metal. Fig. 41 shows the principle of ironing, and where the form has a flange the compressive stresses set up due to the crowding of the metal indicate that a slower punch speed than used for blanking should be used.

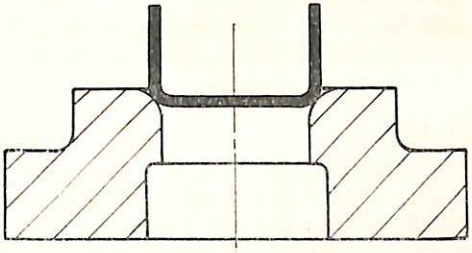


Fig. 41—Die for Redrawing.

Reverse Drawing.

Reverse drawing, or the "inside out" method, is illustrated in Fig. 42. The shell is first of all drawn in the usual cupping die and, after annealing, placed mouth down over the redrawing die, which has a large radius on both its inner and outer edges. The top former then descends and carries out the re-draw.

The great advantage of reverse drawing is that no wrinkling occurs because all the stresses are in tension, and due to this a greater percentage of diameter reduction can be effected than by the normal method.

Both parallel and tapered shells can be drawn in this manner, and as the material clings to the top former, the die remains parallel whilst the top former is shaped to the contour of the shell.

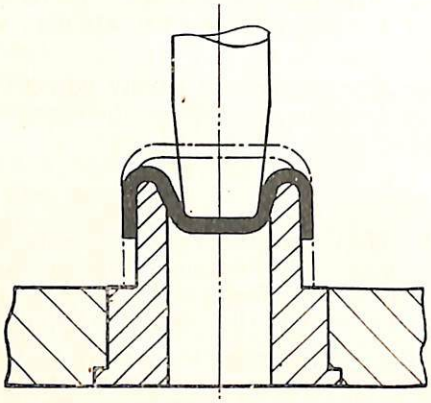


Fig. 42—Reverse Drawing.

Here again, as in all drawing tools, the trapped air must be allowed to escape through a hole in the top former. Failure to provide this outlet causes difficulty in stripping the work and, indeed, the build up of air pressure can cause a fracture on the bottom of the shell, particularly when using very light gauge materials.

Correction of Faults.

The most common trouble is due to shells fracturing at the top or bottom corners. This is caused by attempting to form the cup with too small radii on the punch and die or, again, the blank holder may be exerting too much pressure on the blank.

Tearing of the shell at one particular place may be caused by either high spots on the punch or die, by a build up of particles of swarf on the punch, or by the tool not being set concentrically. The former faults can be cured by polishing the punch and die in the direction of the metal flow.

The lack of an air hole in the punch, simple though it may be, can be a cause of failure, particularly when using a positive stripper, because the vacuum formed by the downward punch stroke makes the cup stick to the punch and the stripper can deform or fracture the work.

Oversize material may cause the die to crack, and in all drawing work, the material thickness must be carefully controlled.

Lubrication.

Due to improved methods of lubrication, steel is being more extensively used for deep drawing, and replacing the more costly

though ductile materials of copper and brass. Coating the steel with copper acts as a lubricant and prevents the metal tearing.

Heavy animal or mineral oil with equal parts of lead or graphite is normally used for drawing steel, soaped water for brass and copper, vaseline for zinc and mineral oil for aluminium.

Calculating Drawing Pressure.

The following formula is sufficiently accurate for most work :

$$P = T \times t \times D \times \pi.$$

where P = drawing pressure in tons.
T = Tensile strength of material in tons.
t = thickness of material.
D = outside dia. of shell (in.).

Chapter 6.

MISCELLANEOUS OPERATIONS.

There are dozens of widely varied and ingenious pressworking operations, far too numerous to describe and illustrate, many of them needing specialised machines, but those described in this chapter are some of the more common processes.

The Guerin Process.

Fig. 43 shows the principles of the Guerin process, which was developed before the war, but is now widely used particularly in the aircraft industry. No top former is needed; instead a pad of rubber is held in the top platen plate and the die is made the form of the work.

As the ram descends, the rubber under pressure forms the material over the bottom die to the required shape.

The process is suitable for shallow forms made from thin ductile materials, and it is usual to see a number of various shapes being formed together.

The time between strokes of the press is brought to a minimum by having as many as six identical die tables placed round the press table and loaded with flat blanks whilst the press is in operation. These tables run on rollers and are slid under the ram in turn.

The rubber pad is kept pressed down for a short period so that the work acquires a set, and when this time has elapsed, a signal, either a buzzer or a light, informs the operator when the ram is to be raised. Very large tonnage presses are required for this operation.

Dinking Dies.

These are mainly hand tools and are used for cutting paper, cardboard, leather and other thin non-ferrous materials. Fig. 44 shows a typical die. The die is forced through the material which is placed on the end grain of a block of hard wood, usually maple. A hole is provided through the die so that the accumulated blanks can be pushed out.

Combination dinking dies are used for cutting washers, and have an inner die working inside the outer one and usually incorporate spring loaded ejectors. Dinking dies can be mounted in line in the power press when quantities merit it.

Assembly Tools.

Many simple assembling operations can be carried out in the press. Ball races and bushes are forced into their housings and small rivetting work is done on an arbor press, which is most suitable for this type of work because the operator can "feel" and regulate the pressure being exerted.

Fig. 45 shows a simple assembly tool used on a twenty-five ton inclinable single-acting power press. This tool is for locking together the two cups shown at the right of the tool, by means of dimpling the walls of the outer one over the edge of the inner cup in three positions.

The two cups are placed, one inside the other, and located in a recess in the plate fixed to the bolster. The inner blank holder

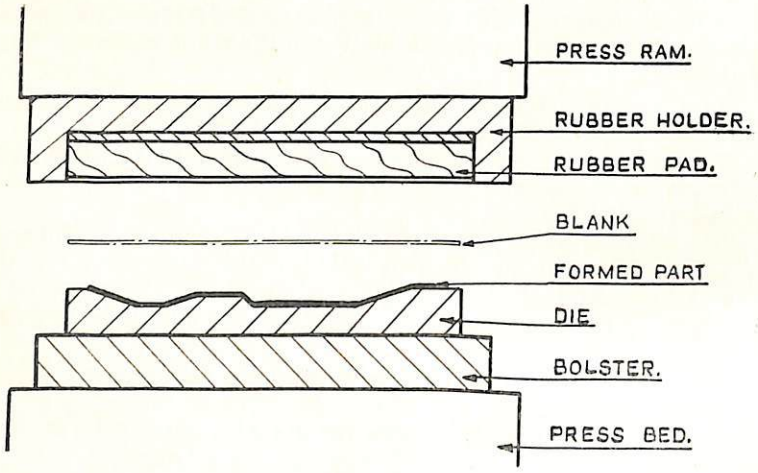


Fig. 43—The Guerin Process.

preceeds the three forming fingers and holds the cups firmly whilst the fingers swing in, being guided in three grooves, and squeeze the wall of the outer cup over.

On the return movement, the spring pad ejects the assembled cups from the blank holder to which they adhere. Three slots are cut into the blank holder to clear the swages and also in the spring pad to miss the fingers, which must be set to form together so that end thrust is equal in the three positions.

Trimming.

These are, in effect, blanking dies, and are used to trim the waved periphery of the flange on a drawn shell and similar pre-pressed parts. The scrap rings so formed are cleared from the tool by a number of wedge shaped cutters spaced around the punch. Care must be taken when setting up these tools, the edges must be in relation to each other or they may spring apart.

Shaving.

Due to the clearance between punch and die, the edges of the blank are never square, particularly so when thick stock is used, and greater clearances are necessary. For most work these edges are quite satisfactory, but for high grade work the edges have to be shaved.

Usually an amount of 10% of the material thickness is shaved off and this has to be allowed for when blanking. The blank must be carefully located and controlled over the die and it is usual to locate the part from pre-pierced holes in it. The punch

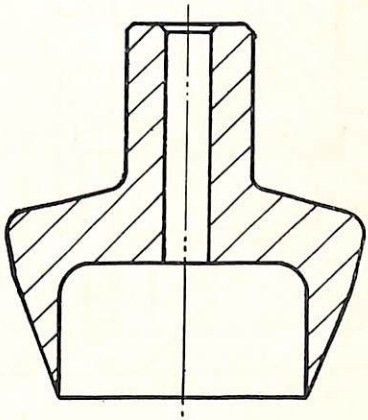


Fig. 44—Dinking Die.

clearance is very slight being no more than 1% of the stock thickness, whilst the die has no clearance at all. The tool should be equipped with guide pillars to ensure perfect alignment.

The blank is carried through the die on a spring loaded pad which ejects the part on the upstroke. Care must be taken to remove the shaving chips, because they can damage the polished die surfaces.

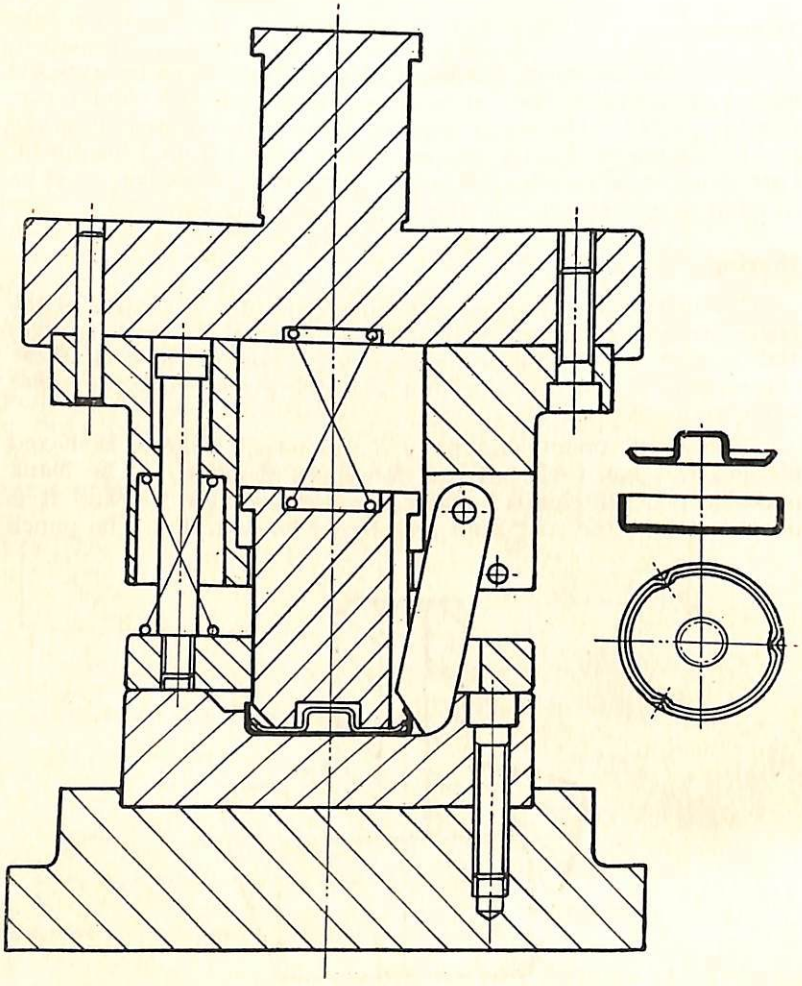


Fig. 45—Assembling Tool.

Burnishing and Broaching.

To obtain a very smooth edge, high grade work must go through a burnishing die after shaving. The die must be very highly polished, it being obvious that the better the finish on the die the better edge obtained on the work. The die is made with a slight taper, the top of which is slightly larger than the blank, and the bottom the required size, running out to a parallel portion, so that the work is compressed and polished at the same time. A punch which pierces and burnishes is shown at Fig. 46. The punch is made ·005″ undersize and long enough to push the piercing clear. The rounded forms on the punch perform the burnishing, and the punch must be provided with an adequate stripper.

Broaching can be carried out successfully on the press and is used for both internal and external cuts, and for opening out pre-formed holes to a desired shape.

The work must be rigidly held in the tool which must be fitted with guide pillars. The operation differs from burnishing in that cutting takes place, but a parallel portion on the broach burnishes the part after the cutting is done.

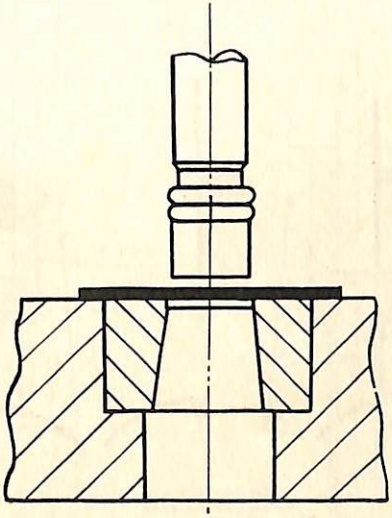


Fig. 46—Burnishing Punch.

Planishing.

This is a straightforward operation to flatten cut blanks and to remove the raised edge, and the tool is made with two flat hardened formers which must be parallel to each other.

"Pin-point" planishing is carried out with flat serrated formers, the serrations ending in a series of points. This tool is used for flattening springly metals and relieves surface stresses, but leaves a series of pin point indentations on the work. Planishing is also used for flattening the two surfaces on a cranked component, and this operation is usually known as "setting."

Plunging.

This operation consists of forcing the surrounding material of an already pierced hole through a die, so that a deep boss can be formed, thus eliminating the welding on of pads or nuts. The plunging punch is usually made acorn shaped to give a good lead in, and the material can also be ironed to give a deeper plunged portion.

The operation is encountered in sheet metal products, the plunging usually being to accommodate a screw.

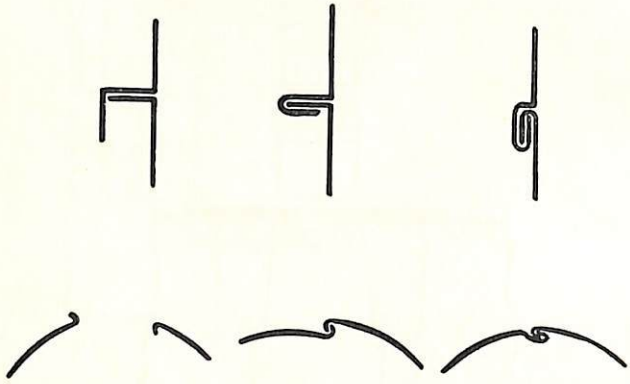
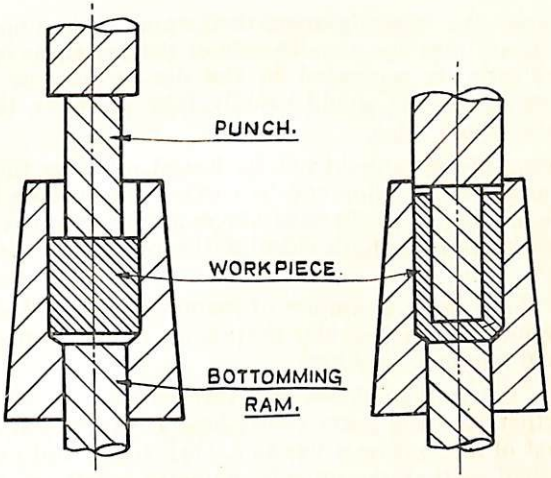
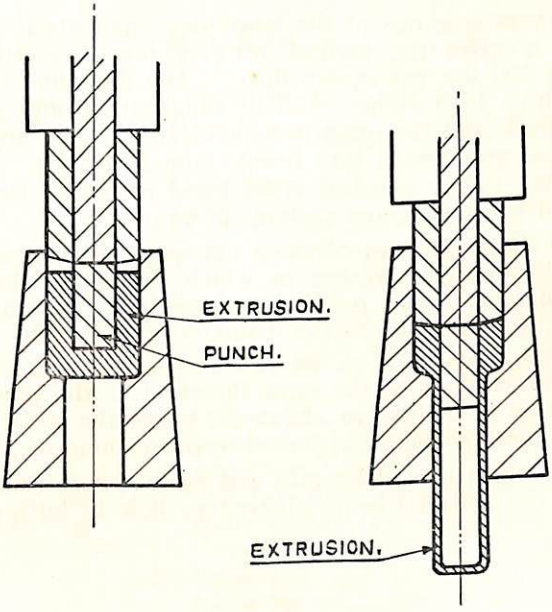


Fig. 47—Types of Seaming.



Backward Extruding.



Forward Extruding.

Fig. 48—Cold Extruding.

Curling and Seaming.

Both these are bending operations, and it is important in curling to ensure that the smooth side of the metal, as opposed to the blanked side, is presented to the die surface, or otherwise deterioration of the die would rapidly take place by the scoring action of the rough edge.

The radius of curl should not be less than twice the material thickness, and the operation can be carried out on long lengths of stock in the press brake. Pressed hinges are made at one operation by feeding blanks from both sides of the press and curling them together.

Fig. 47 shows some examples of seaming. Round articles are made by spinning, but irregular shapes are either formed by hand or by special seaming machines.

The top illustration shows the three stages in seaming two sheets together, and the lower shows how a tube is seamed. The blank is first of all bent on a vee tool, then rolled and jointed, and finally finished so that the outside diameter is left smooth.

Cold Extruding.

Cold extrusion is one of the latest developments in press tool work and involves the highest working pressures, these being upwards of 100 ton per square inch. The dies, for this reason, are made from high carbon steel or tungsten carbide, depending upon the work and the quantities involved. They are made of small section and forced into heavy forged bolsters. The dies must be very highly polished and lapped to reduce the working friction and to prevent any pick-up of swarf.

Fig. 48 shows the two common extrusion principles. Above is shown backward extrusion in which the metal flows in an opposite direction to the punch travel and the practical limit for punch length is three times the diameter of the work.

The lower illustration shows two stages in forward extrusion. Here the metal flows in the same direction as the punch travel. The extrusion is limited to about six times the work diameter, because of the high power absorbed in overcoming friction.

The two operations of forward and backward extruding can be combined, the material being allowed to flow in both directions.

TABLE 1.

SHEAR STRENGTHS.

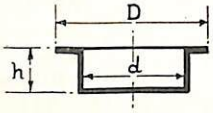
Material	*Tons Per Sq. In.*
Aluminium.	
Cast	6
Soft Sheet	7½
H.H. Sheet	9½
Hard Sheet	12½
Asbestos.	
Millboard	2
Brass.	
Cast	18
Soft Sheet	15
H.H. Sheet	17½
Hard Sheet	20
Bronze.	
Gunmetal	16
Phosphor	20
Copper.	
Cast	12½
Rolled	14
Cupro Nickel	20
Duralumin.	
Soft Sheet	15
Treated	17½
Treated and Cold Rolled	20
Fibre.	
Hard	12

Material	*Tons Per Sq. In.*
Iron.	
Cast	12½
2% Nickel	25
Wrought	20
Lead	2
Leather.	
Chrome	3½
Oak	3½
Rawhide	6½
Monel Metal.	
Cast	30
Rolled Sheet	32½
Nickel Silver.	
H.H. Sheet	16
Silver	15
Steel.	
Casting	30
Boiler Plate	30
Angle Iron	30
Cold Drn. Rod	29
Drill Rod Not Temp.	40
Nickel 3½%	41
Nickel 5%	42½
Silicon Sheet	32½
Stainless Sheet	35

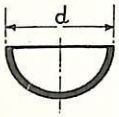
Material	*Tons Per Sq. In.*
Steel.	
·10 Carbon Soft	22½
·25 Carbon Mild	25
·50 Carbon	35
·75 Carbon	40
1·0 Carbon	42½
1·2 Carbon Not Temp.	47
1·2 Carbon Temp.	95
Hot $\frac{1}{0}$ to $\frac{1}{4}$ Off Cold Strength For Steel	
Tin.	
Cast	3
Rolled Sheet	2½
Sheet Steel	25
Zinc.	
Sand Cast	7
Die Cast	8
Rolled Sheet	9
Hard Rolled	10
Paper.	
Hollow Die	1½
Flat Punch	4¼
Bristol Flat Punch	2½
Strawboard Flat Punch	1¾

TABLE 2.

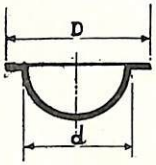
To Find Blank Diameter of Cylindrical Shells.



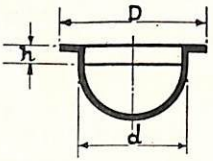
$\sqrt{D^2 + 4dh}$.



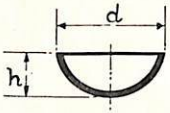
$\sqrt{2d^2 + 1{\cdot}414\,d}$



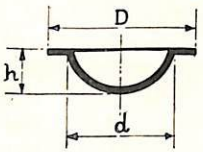
$\sqrt{d^2 + D^2}$



$\sqrt{d^2 + D^2 + 4dh}$.



$\sqrt{d^2 + 4h^2}$



$\sqrt{D^2 + 4h^2}$

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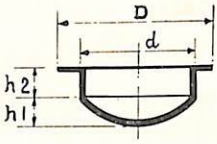
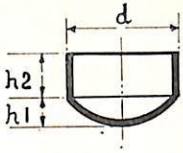
TABLE 3.

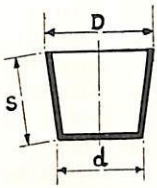
To Find Blank Diameter of Cylindrical Shells.



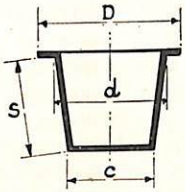
$$\sqrt{D^2 + 4(h1^2 + d\,h2)}$$



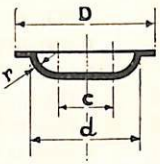
$$\sqrt{d^2 + 4(h1^2 + d\,h2)}$$



$$\sqrt{d^2 + 2s(d + D)}$$



$$\sqrt{c^2 + 2s(c+d) + D^2 - d^2}$$



$$\sqrt{c^2 + 6{\cdot}28\,rc + 8r^2 + D^2 - d^2}$$

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TABLE 4.

WEIGHTS OF MATERIALS.

MATERIAL	SPECIFIC GRAVITY	WEIGHT IN LBS. PER		
		CUB. IN.	SQ. INCH ·001″ THICK	SQ. FOOT ·001″ THICK
Aluminium 99·4%	2·706	0·0977	0·0000977	0·0140688
Aluminium Alloy D.T.D. 249	2·7	0·0975	0·0000975	0·0140400
,, ,, D.T.D. 290	2·8	0·1011	0·0001011	0·0145584
Aluminium Magnesium Alloy	2·68	0·0967	0·0000967	0·0139248
,, Manganese Alloy	2·7	0·0975	0·0000975	0·0140400
Antimony	6·71	0·2422	0·0002422	0·0348768
Asbestos	2·8	0·1011	0·0001011	0·0145584
Bronze Phosphor 92/8 ...	8·8	0·3177	0·0003177	0·0457488
Bismuth	9·8	0·3538	0·0003538	0·0509472
Brass 65/35	8·47	0·3058	0·0003058	0·0440352
Bronze 2/10/88	8·78	0·3170	0·0003170	0·045648
,, Phos. Sht.	8·8	0·3180	0·0003180	0·0457920
Celluloid	1·35	0·0487	0·0000487	0·0070128
Chromium	6·5	0·2347	0·0002347	0·0337968
Copper	8·93	0·3224	0·0003224	0·0464256
Cork	0·24	0·0087	0·0000087	0·0012528
Dow Metal Magnesium ...	1·78	0·0643	0·0000643	0·0092592
Duralumin	2·85	0·1029	0·0001029	0·0148176
Ebony Wood Dry	1·25	0·045	0·000045	0·00648
Elektron	1·83	0·0661	0·0000661	0·0095184
Fibre Vulcanized	1·41	0·0510	0·000051	0·007344
Gold Cast Hammered ...	19·32	0·6975	0·0006975	0·10044
Iridium	22·42	0·8094	0·0008094	0·1165536
Iron Cast	7·2	0·2599	0·0002599	0·0374256
,, Ferrosilicon	7·01	0·2530	0·0002530	0·036432
,, Pure	7·87	0·2841	0·0002841	0·0409104
,, Sheet	7·7	0·2780	0·0002780	0·040032
,, Wrought	7·78	0·2807	0·0002807	0·0404208
Lead	11·37	0·4105	0·0004105	0·059112
Leather	0·94	0·0341	0·0000341	0·0049104

TABLE 5.

WEIGHTS OF MATERIALS.

Continued

MATERIAL	Specific Gravity	WEIGHT IN LBS. PER		
		Cub. In.	Sq. Inch ·001″ Thick	Sq. Foot ·001″ Thick
Magnesium	1·74	0·0628	0·0000628	0·0090432
7% ,, Aluminium Alloy	2·63	0·0949	0·0000949	0·0136656
Manganese	7·42	0·2679	0·0002679	0·0385776
Mercury	13·6	0·4910		
Mica	2·8	0·1011	0·0001011	0·0145584
Micarta	1·24	0·0446	0·0000446	0·0064224
Molybdenum	10·2	0·3682	0·0003682	0·0530208
Monel Metal Cast	8·8	0·3177	0·0003177	0·0457488
,, ,, Rolled ...	8·9	0·3212	0·0003212	0·0462528
Nickel	8·8	0·3177	0·0003177	0·0457488
45% Nickel Alloy	8·0	0·2888	0·0002888	0·0415872
Paper	0·93	0·0336	0·0000336	0·0048384
Pewter	7·49	0·2703	0·0002703	0·0389232
Platinum Sheet	21·54	0·7776	0·0007776	0·1119744
,, Wire	21·04	0·7595	0·0007595	0·109368
Rubber Soft	0·95	0·0341	0·0000341	0·0049104
,, Hard Ebonite ...	1·15	0·0416	0·0000416	0·0059904
Silicon	2·42	0·0874	0·0000874	0·0125856
Silver	10·78	0·3890	0·000389	0·056016
,, German or Nickel ...	8·75	0·3160	0·000316	0·045504
Steel Crucible Sheet ...	7·9	0·2853	0·0002853	0·0410832
,, Machinery	7·81	0·2818	0·0002818	0·0405792
,, Rolled Sheet	7·85	0·2833	0·0002833	0·0407952
,, Stainless	8·4	0·3033	0·0003033	0·0436752
,, Tool	7·9	0·2853	0·0002853	0·0410832
,, 2½% Silicon Transformer Grade	7·42	0·268	0·000268	0·038592
Tin	7·30	0·2635	0·0002635	0·037944
Tungsten	18·77	0·6776	0·0006776	0·0975744
Vanadium	5·5	0·1986	0·0001986	0·0285984
Zinc Cast	7·11	0·2567	0·0002567	0·0369648
,, Rolled	7·2	0·26	0·000260	0·03744

TABLE 6.

BRITISH IMPERIAL WIRE GAUGE (S.W.G.).

No.	Size Ins.	No.	Size Ins.	No.	Size Ins.
0000000	·500	13	·092	32	·0108
000000	·464	14	·080	33	·0100
00000	·432	15	·072	34	·0092
0000	·400	16	·064	35	·0084
000	·372	17	·056	36	·0076
00	·348	18	·048	37	·0068
0	·324	19	·040	38	·0060
1	·300	20	·036	39	·0052
2	·276	21	·032	40	·0048
3	·252	22	·028	41	·0044
4	·232	23	·024	42	·0040
5	·212	24	·022	43	·0036
6	·192	25	·020	44	·0032
7	·176	26	·018	45	·0028
8	·160	27	·0164	46	·0024
9	·144	28	·0148	47	·0020
10	·128	29	·0136	48	·0016
11	·116	30	·0124	49	·0012
12	·104	31	·0116	50	·0010

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List of A.E.S.D. Data Sheets.

1. Safe Load on Machine-Cut Spur Gears.
2. Deflection of Shafts and Beams
3. Deflection of Shafts and Beams (Instruction Sheet) } Connected.
4. Steam Radiation Heating Chart.
5. Horse-Power of Leather Belts, etc.
6. Automobile Brakes (Axle Brakes)
7. Automobile Brakes (Transmission Brakes) } Connected.
8. Capacities of Bucket Elevators.
9. Valley Angle Chart for Hoppers and Chutes.
10. Shafts up to $5\frac{1}{2}$-in. diameter, subjected to Twisting and Combined Bending and Twisting.
11. Shafts, $5\frac{3}{4}$ to 26 inch diameter, subjected to Twisting and Combined Bending and Twisting.
12. Ship Derrick Booms.
13. Spiral Springs (Diameter of Rd. or Sq. Wire).
14. Spiral Springs (Compression).
15. Automobile Clutches (Cone Clutches).
16. ,, ,, (Plate Clutches).
17. Coil Friction for Belts, etc.
18. Internal Expanding Brakes. Self-Balancing Brake Shoes (Force Diagram) } Connected.
19. Internal Expanding Brakes. Angular Proportions for Self-Balancing. }
20. Referred Mean Pressure Cut-Off, etc.
21. Particulars for Balata Belt Drives.
22. $\frac{1}{2}$" Square Duralumin Tubes as Struts.
23. 1 ,, ,, ,, ,,
24. $\frac{3}{4}$" Sq. Steel Tubes as Struts (30 ton yield).
25. $\frac{7}{8}$" ,, ,, ,, (30 ton yield).
26. 1" ,, ,, ,, (30 ton yield).
27. $\frac{3}{4}$" ,, ,, ,, (40 ton yield).
28. $\frac{7}{8}$" ,, ,, ,, (40 ton yield).
29. 1" ,, ,, ,, (40 ton yield).
30. Moments of Inertia of Built-up Sections (Tables)
31. Moments of Inertia of Built-up Sections (Instructions and Examples) } Connected.
34. Capacity and Speed Chart for Troughed Band Conveyors.
35. Screw Propeller Design (Sheet 1, Diameter Chart)
36. ,, ,, ,, (Sheet 2, Pitch Chart)
37. ,, ,, ,, (Sheet 3, Notes and Examples) } Connected.
38. Open Coil Conical Springs.
39. Close Coil Conical Springs.
40. Trajectory Described by Belt Conveyors (Revised 1949).
41. Metric Equivalents.
42. Useful Conversion Factors.
43. Torsion of Non-Circular Shafts.
44. Railway Vehicles on Curves.
46. Coned Plate Development.
47. Solution of Triangles (Sheet 1, Right Angles),
48. Solution of Triangles (Sheet 2, Oblique Angles).
49. Relation between Length, Linear Movement and Angular Movement of Lever (Diagram and Notes).
50. ,, ,, (Chart).
51. Helix Angle and Efficiency of Screws and Worms.
52. Approximate Radius of Gyration of Various Sections.

53. Helical Spring Graphs (Round Wire).
54. ,, ,, ,, (Round Wire).
55. ,, ,, ,, (Square Wire).
} Connected.

56. Relative Value of Welds to Rivets.
58. Graphs for Strength of Rectangular Flat Plates of Uniform Thickness.
59. Graphs for Deflection of Rectangular Flat Plates of Uniform Thickness.
61. Deflection of Leaf Spring.
62. Strength of Leaf Spring.
63. Chart Showing Relationship of Various Hardness Tests.
64. Shaft Horse Power and Proportions of Worm Gear.
65. Ring with Uniform Internal Load (Tangential Strain).
66. Ring with Uniform Internal Load (Tangential Stress).
} Connected.

67. Hub Pressed on to Steel Shaft. (Maximum Tangential Stress at Bore of Hub).
68. Hub Pressed on to Steel Shaft. (Radial Gripping Pressure between Hub and Shaft).
69. Rotating Disc (Steel) Tangential Strain.
70. ,, ,, ,, Stress.
} Connected.

71. Ring with Uniform External Load, Tangential Strain.
72. ,, ,, ,, ,, ,, Stress.
} Connected.

73. Viscosity Temperature Chart for Converting Commercial to Absolute Viscosities.
74. Journal Friction on Bearings.
75. Ring Oil Bearings.
} Connected.

76. Shearing and Bearing Values for High Tensile Structural Steel Shop Rivets, in accordance with B.S.S. No. 548/1934.
78. Velocity of Flow in Pipes for a Given Delivery.
79. Delivery of Water in Pipes for a Given Head.
} Connected.

80. (See No. 105).
81. Involute Toothed Gearing Chart.
83. Variation of Suction Lift and Temperature for Centrifugal Pumps.
89. Curve Relating Natural Frequency and Deflection.
90. Vibration Transmissibility Curved or Elastic Suspension.
91. Instructions and Examples in the Use of Data Sheets, Nos. 89 and 90.
} Connected.

92. Pressure on Sides of Bunker.
93-4-5-6-7. Rolled Steel Sections.
98-99-100. Boiler Safety Valves.
102. Pressure Required for Blanking and Piercing.
103. Punch and Die Clearances for Blanking and Piercing.
104. Nomograph for Valley Angles of Hoppers and Chutes.
105. Permissible Working Stresses in Mild Steel Struts with B.S. 449, 1948.
106. Compound Cylinder (Similar Material) Radial Pressure of Common Diameter (D1).
107. True Angles for Pipe Bends.
108. Development of Spiral Chutes.

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